

San Diego Region Lagoon TMDLs Phase I – Data Compilation and Model Configuration

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1 Introduction

1.1 PURPOSES OF CURRENT WORK

Total Maximum Daily Loads (TMDLs) for indicator bacteria were developed to address 19 of the 38 bacteria-impaired waterbodies in the San Diego region, as identified on the 2002 Clean Water Act Section 303(d) List of Water Quality Limited Segments. This project is referred to as “Project I Beaches and Creeks in the San Diego Region” or Bacti-I and is documented in San Diego Water Board (2007). An expansion of the regional modeling approach used in Bacti-I was conducted under Bacteria Impaired Waters TMDL Project II for Bays and Lagoons (Bacti-II) and included representation of watersheds draining to impaired lagoons (San Diego Water Board and USEPA, 2005). The present study builds on this work and provides initial model configuration and data compilation to support development of TMDLs for numerous parameters in 11 lagoons, adjacent beaches, and creeks located in the San Diego region.

TMDLs will be developed for at least one of the following constituents: sediments, total dissolved solids, enteric bacteria, and/or nutrients. The 11 waterbodies include the Santa Margarita Lagoon, Loma Alto Slough, Pacific Ocean Shoreline (at Loma Alto Slough), Agua Hedionda Lagoon, Agua Hedionda Creek, San Elijo Lagoon, Pacific Ocean Shoreline (at San Elijo Lagoon), Buena Vista Lagoon, Pacific Ocean Shoreline (at Buena Vista Lagoon), Los Penasquitos Lagoon, and the Famosa Slough and Channel.

Regional Board Investigation Order No. R9-2005-0216 requires stakeholders to collect necessary data to support model development for the 11 waterbodies planned for TMDL development. Monitoring began in fall 2007 and will continue until fall 2008. To prepare for the data collected, Tetra Tech has been tasked to configure watershed and receiving water models of the lagoons. The technical approach for development of these models is based on evaluation of technical, regulatory, and user criteria for the lagoon systems (Tetra Tech, 2008). Technical criteria refer to the model’s simulation of the physical system in question, including watershed and/or stream characteristics/processes and constituents of interest. Regulatory criteria make up the constraints imposed by regulations, such as water quality standards or procedural protocol. User criteria comprise the operational or economical constraints imposed by the end-user and include factors such as hardware/software compatibility and financial resources.

Tetra Tech is building upon previous modeling efforts where possible to support the modeling effort. Specifically, the Loading Simulation Program C++ (LSPC) model (Tetra Tech and USEPA, 2002) frameworks previously developed to support the Bacti-I and Bacti-II projects are being used to address watershed loadings. New LSPC models for Los Penasquitos Lagoon and Famosa Slough have been created because they were not included in the earlier work, though work in the Miramar area provided an initial basis for Los Penasquitos. An LSPC model of the Santa Margarita watershed was developed under Bacti-I. At the request of the Regional Board, this model has been converted to the WinHSPF format. New receiving water models are being developed for seven lagoons or sloughs using the Environmental Fluid Dynamics Code or EFDC model (Hamrick, 1992; Tetra Tech, 2007). The approach to address impairments of the Pacific Ocean shorelines near three of the lagoons has yet to be determined.

The present report describes model configuration and monitoring data compilation support for TMDL development. Complete calibration and validation will occur in the next phase of the project and will utilize the monitoring data still being collected. This report serves to document the current status of the models and the steps required to complete model calibration in Phase II.

1.2 LAGOON USE IMPAIRMENT LISTINGS

Santa Margarita Lagoon, Loma Alto Slough, Pacific Ocean Shoreline (at Loma Alto Slough), Agua Hedionda Lagoon, Agua Hedionda Creek, San Elijo Lagoon, Pacific Ocean Shoreline (at San Elijo Lagoon), Buena Vista Lagoon, Pacific Ocean Shoreline (at Buena Vista Lagoon), Los Penasquitos Lagoon, and the Famosa Slough and Channel have been added to the State's list of impaired waterbodies, the 303(d) list, for at least one of the following constituents: sediments, total dissolved solids, enteric bacteria, and/or nutrients (Table 1). Watershed runoff, coupled with reduced tidal influence from restricted inlets, has resulted in beneficial use impairments in many systems, including low dissolved oxygen, excessive algal growth, eutrophication, presence of pathogens, excessive sedimentation and suspended sediment.

Table 1. Summary of 303(d) Listings by Waterbody

Waterbody Name	Extent of Impairment	Pollutant Name
Santa Margarita Lagoon	1.0 acres	Eutrophic
Loma Alto Slough	8.2 acres	Eutrophic, Indicator Bacteria
Pacific Ocean Shoreline (at Loma Alto Slough)	1.1 miles	Indicator Bacteria
Agua Hedionda Lagoon	6.8 acres	Sedimentation/Siltation, Indicator Bacteria
Agua Hedionda Creek	7.0 miles	Total Dissolved Solids
San Elijo Lagoon	330 acres	Eutrophic, Sedimentation/Siltation, Indicator Bacteria
Pacific Ocean Shoreline (at San Elijo Lagoon)	0.44 mile	Indicator Bacteria
Buena Vista Lagoon	202 acres	Sedimentation/Siltation, Nutrients, Indicator Bacteria
Pacific Ocean Shoreline (at Buena Vista Lagoon)	1.2 miles	Indicator Bacteria
Los Penasquitos Lagoon	469 acres	Sedimentation/Siltation
Famosa Slough and Channel	32 acres	Eutrophic Condition

1.3 PARAMETERS OF INTEREST

The parameters of interest for TMDL development include nutrients (nitrogen and phosphorus) and dissolved oxygen to address the eutrophic conditions and nutrient impairments, indicator bacteria (fecal coliform, enterococcus, and total coliform), total dissolved solids, and sediment to address sedimentation/siltation impairments.

In selecting a modeling system to address these parameters of interest, consideration was given to the regulatory targets stated in the Water Quality Control Plan for the San Diego Basin (Basin Plan) for TMDL development. The selected model must be capable of simulating these water quality parameters using time-series simulation so that applicable averaging periods and peak levels can be determined and compared to numeric targets. The selected model must also be able to address seasonal variations in

hydrology and water quality as well as critical conditions (i.e., periods when bacteria concentrations are at their highest or dissolved oxygen at its lowest) as required by TMDL regulations. LSPC and EFDC models provide time-variable output and allow evaluation of all types of criteria (static or dynamic).

1.3.1 Nitrogen and Phosphorus

The Basin Plan states threshold levels for nitrogen and phosphorus. The water quality objective (WQO) for biostimulatory substances (phosphorus and nitrogen) is as follows:

Inland surface waters, bays and estuaries and coastal lagoon waters shall not contain biostimulatory substances in concentrations that promote aquatic growth to the extent that such growths cause nuisance or adversely affect beneficial uses.

Concentrations of nitrogen and phosphorus, by themselves or in combination with other nutrients, shall be maintained at levels below those which stimulate algae and emergent plant growth. Threshold total Phosphorus (P) concentrations shall not exceed 0.05 mg/l in any stream at the point where it enters any standing body of water, nor 0.025 mg/l in any standing body of water. A desired goal in order to prevent plant nuisances in streams and other flowing waters appears to be 0.1 mg/l total P. These values are not to be exceeded more than 10% of the time unless studies of the specific body in question clearly show that water quality objective changes are permissible and changes are approved by the Regional Board. Analogous threshold values have not been set for nitrogen compounds; however, natural ratios of nitrogen to phosphorus are to be determined by surveillance and monitoring and upheld. If data are lacking, a ratio of N:P=10:1 shall be used. Note: Certain exceptions to the above water quality objectives are described in Chapter 4 in the sections titled Discharges to Coastal Lagoons from Pilot Water Reclamation Projects and Discharges to Surface Waters.

1.3.2 Dissolved Oxygen

Dissolved Oxygen (DO) criteria consist of both daily average and daily minimum levels and are applicable throughout the year. Time-variable modeling permits evaluation of both criteria. The WQO for DO is set as follows:

Dissolved oxygen levels shall not be less than 5.0 mg/l in inland surface waters with designated MAR or WARM beneficial uses or less than 6.0 mg/l in waters with designated COLD beneficial uses. The annual mean dissolved oxygen concentration shall not be less than 7 mg/l more than 10% of the time.

1.3.3 Bacteria

The Basin Plan identifies bacteria water quality objectives for the designated uses of the lagoons. All seven lagoons have a contact recreation and non-contact recreation beneficial use criteria, with Famosa Slough, Los Penasquitos and Agua Hedionda Lagoon having a shellfish harvesting beneficial use criteria.

Contact Recreation:

In waters designated for contact recreation (REC-1), the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period, shall not exceed a log mean of 200/100 milliliters (ml), nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml.

The USEPA published E. coli and enterococci bacteriological criteria applicable to waters designated for contact recreation (REC-1) in the Federal Register, Vol. 51, No. 45, Friday, March 7, 1986, 8012-8016.

Water Quality Objective for Enterococci and E. coli:**USEPA BACTERIOLOGICAL CRITERIA FOR WATER CONTACT RECREATION^{1,2}**
(in colonies per 100 ml)

	Freshwater		Saltwater
	Enterococci	E. coli	Enterococci
<i>Steady State</i>			
<i>(all areas)</i>	33	126	35
<i>Maximum</i>			
<i>(designated beach)</i>	61	235	104
<i>(moderately or lightly used area)</i>	108	406	276
<i>(infrequently used area)</i>	151	576	500

Non-Contact Recreation:

In waters designated for non-contact recreation (REC-2) and not designated for contact recreation (REC-1), the average fecal coliform concentrations for any 30-day period, shall not exceed 2,000/100 ml nor shall more than 10 percent of samples collected during any 30-day period exceed 4,000/100 ml.

Shellfish Harvesting:

In waters where shellfish harvesting for human consumption, commercial or sports purposes is designated (SHELL), the median total coliform concentration throughout the water column for any 30-day period shall not exceed 70/100 ml nor shall more than 10 percent of the samples collected during any 30-day period exceed 230/100 ml for a five-tube decimal dilution test or 330/100 ml when a three-tube decimal dilution test is used.

1.3.4 Total Dissolved Solids

Total Dissolved Solids (TDS) criteria exist for both surface water and groundwater. For Agua Hedionda Creek, the inland surface water and groundwater criteria are listed as 500 mg/L and 1,200 mg/L, respectively. The concentrations are not to be exceeded more than 10 percent of the time during a one year period. Modeling will address only the surface water criteria.

1.3.5 Sediment

No numeric criteria exist for suspended sediment. The narrative criteria as stated in the Basin Plan is as follows:

The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

1.4 CURRENT STATUS OF MODELS

LSPC/HSPF watershed models and EFDC receiving lagoon models have been configured for seven lagoons, and initial testing was conducted. Initial testing of hydrology focused on Santa Margarita and Agua Hedionda watershed models and suggests the need for continued refinement in Phase II. Additional

bathymetry data for Los Penasquitos Lagoon, San Elijo Lagoon, and Santa Margarita Estuary are needed to complete grid development. Calibration of water quality parameters in watershed and receiving water models will be conducted in Phase II following the completion of the ongoing, intensive monitoring effort.

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2 Watershed Models

2.1 EXISTING MODELS

The watershed model extent for the previous Bacti-I work covers most of the area of interest, although two additional watersheds for Los Penasquitos Lagoon and Famosa Slough have been added (Figure 1). These models have previously been calibrated for wet weather hydrology and bacterial loads, but not for the other parameters of concern. In addition, the model is not calibrated for dry weather flows, as these flows result from a combination of the management and use of imported water, along with complicated interactions with groundwater.

Previous work for the Bacti-I models included calibration for wet weather hydrology for 1992-2001, using 2000 land use data. For the present effort, the model was updated to include the most recent land use data. In addition, the simulation period will initially be extended through 2006, and later extended to include the new sampling period (2007-2008) during Phase II.

2.2 UPDATES TO EXTERNAL DATA

2.2.1 Meteorology

Meteorological data are a critical component of the watershed model. Appropriate representation of precipitation, temperature, and potential evapotranspiration are required to characterize hydrology in a watershed model. Depending on the selected modules, wind speed, cloud cover, and dew point may also be required to develop a valid model. These data provide necessary input to LSPC algorithms for hydrologic and water quality representation. In general, hourly precipitation data are recommended for nonpoint source modeling, since the algorithms for wash-off are storm-intensity driven.

Weather data through 2001 were assembled for the Bacti-I modeling effort. A Quality Assurance review has been conducted for these data as part of the present effort and some missing data have been replaced. The same weather stations have been extended through 2006. In the next phase of the project, the meteorological time series will be extended to include the new sampling period (2007-2008).

Rainfall, wind speed and direction, air temperature, and relative humidity are currently being monitored at a minimum of one site per watershed, measured daily from October 2007 to October 2008 under the TMDL monitoring program that is ongoing.

2.2.1.1 Precipitation

Hourly rainfall data were obtained from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). To augment the NCDC data, hourly rainfall data were also obtained from the California Irrigation Management Information System (CIMIS); and the ALERT (Automatic Local Evaluation in Real-Time) Flood Warning System. Stations used in the modeling effort are mapped in Figure 2 and listed in Table 2.

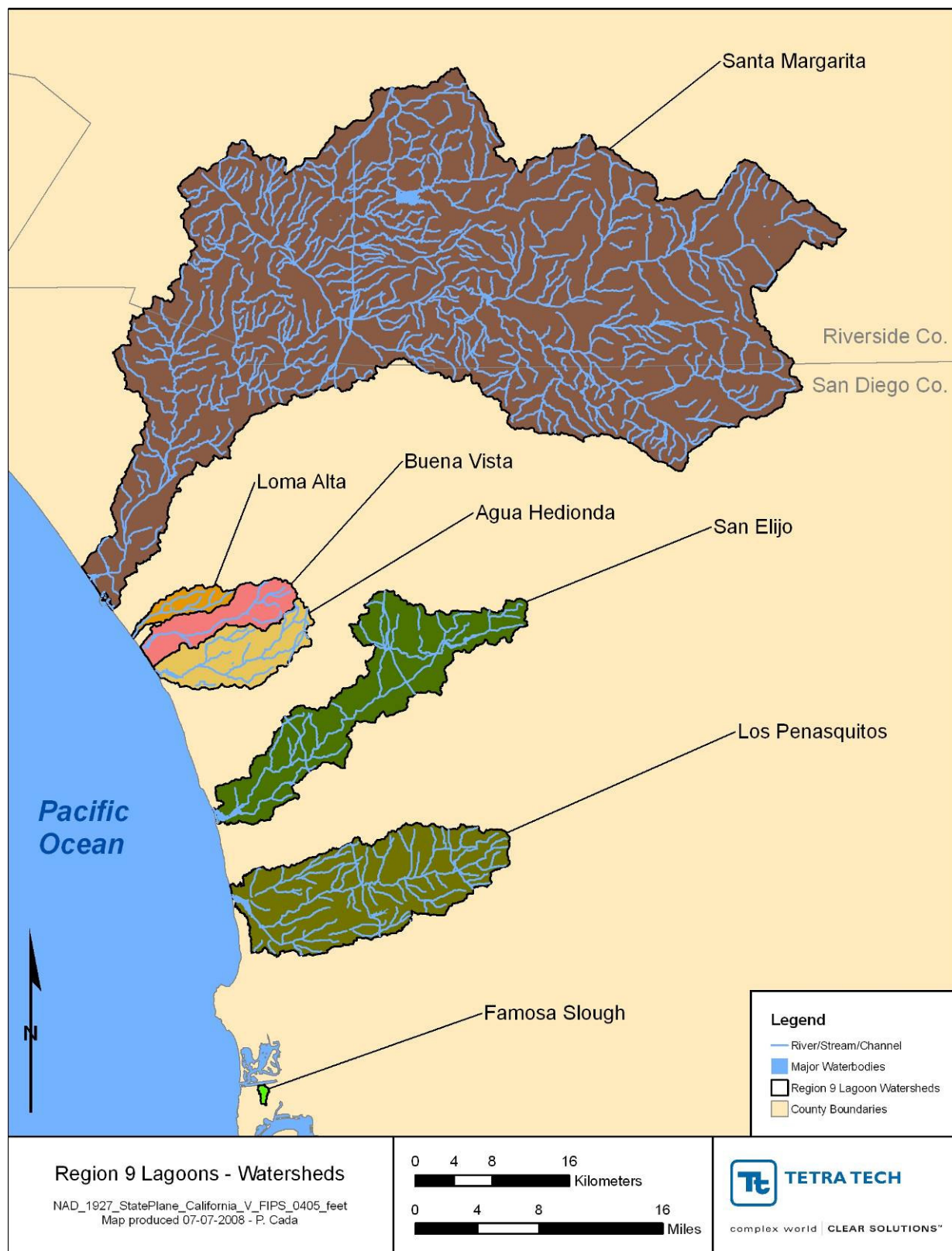


Figure 1. Locations of Model Watersheds



Figure 2. Weather Stations Used in Modeling Scenarios

Table 2. Weather Stations

Weather Station	Source
CA2239	NCDC
CA4650	NCDC
CA6319	NCDC
CA6379	NCDC
CA7837	NCDC
CA8844	NCDC
CA8992	NCDC
Alert21	ALERT
Alert22	ALERT
Alert24	ALERT
Alert52	ALERT
Alert53	ALERT
Alert81	ALERT
CIMIS74	CIMIS

Because rainfall gages are not always in operation and accurately recording data, the resulting dataset may contain various intervals of accumulated, missing, or deleted data. Missing or deleted intervals are periods over which either the rainfall gage malfunctioned or the data records were somehow lost. Accumulated intervals represent cumulative precipitation over several hours, but the exact hourly distribution of the data is unknown. To address the incomplete portions, it is necessary to patch the rainfall data with information from nearby gages. The precipitation records were patched as needed using Tetra Tech's MetAdapt tool.

2.2.1.2 Evapotranspiration

Evapotranspiration (ET) time series for each weather station were updated to reflect the appropriate CIMIS evapotranspiration zone. In the prior work, ET rates from CIMIS stations in the study area were averaged to determine one ET time series for all of the weather stations. To improve upon this approach, ET data were obtained from CIMIS for seven stations and used to develop hourly ET time series for each of the five ET zones.

Table 3 summarizes the CIMIS stations used to assign hourly ET values to each of the weather stations used in the LSPC/HSPF models. The primary stations used to develop a time series were chosen based on proximity to the weather station, matching ET zone, and dates of activity matching the simulation period. For days where a primary station did not record ET, a secondary station was used to patch the missing dates. In most cases, the secondary station was in a different ET zone than the weather station and its primary station(s). A ratio of the average annual ET over the simulation period was used to scale up or down the secondary ET values as needed.

Some subbasins were originally assigned to a weather station in coastal Zone 1. Because evapotranspiration in this zone is extremely low due to heavy fog, only those subbasins at least halfway

within Zone 1 were assigned to a Zone 1 weather station. These include subbasins 901, 904, 1201, 2100, 1401, 1402, and 1404.

Table 3. Assignment of CIMIS ET Data to Each Weather Station

ET Zone	Primary CIMIS Stations and Dates of Activity	Secondary CIMIS Stations and Dates of Activity	Weather Stations
1	CIMIS173 (11/29/00 to 12/31/06)	CIMIS66 (1/1/90 to 12/18/01) CIMIS184 (4/19/02 to 12/31/06)	Alert22
3	CIMIS66 (1/1/90 to 12/18/01) CIMIS184 (4/19/02 to 12/31/06)	CIMIS49 (1/1/90 to 4/17/02) CIMIS153 (2/1/99 to 12/31/06)	CA6379
6	CIMIS62 (1/1/90 to 12/31/06)	CIMIS74 (1/1/90 to 2/29/98) CIMIS153 (2/1/99 to 12/31/06)	CA8844, Alert24
9	CIMIS74 (1/1/90 to 2/29/98) CIMIS153 (2/1/99 to 12/31/06)	CIMIS62 (1/1/90 to 12/31/06)	CA6319, CIMIC74
16	No CIMIS stations in Zone 16 of southern California	CIMIS173 (11/29/00 to 12/31/06) CIMIS66 (1/1/90 to 12/18/01) CIMIS184 (4/19/02 to 12/31/06)	CAW052

2.2.2 Land Use

The watershed model requires a basis for distributing hydrologic and pollutant loading parameters. This is necessary to appropriately represent hydrologic variability throughout the basin, which is influenced by land surface and subsurface characteristics. It is also necessary to represent variability in pollutant loading, which is highly correlated to land practices and geology and will be used to allocate allowable loadings to nonpoint sources. The basis for this distribution is provided by the available soils coverage and land use data.

LSPC algorithms require that land use categories be divided into separate pervious and impervious land units for modeling. This division has been made for the appropriate land use classes. LSPC model algorithms that simulate hydrologic and pollutant loading processes for pervious and impervious lands are then applied to the corresponding land units.

The existing Bacti-I models were based on 2000 land use. This has been updated with more recent data. In evaluating calibration, it will be important to recognize that some of the watersheds have experienced significant increases in development over this time period.

Land use data used for the project was extracted from a composite of locally developed GIS data layers. Two sources of data, the San Diego Association of Governments (SANDAG) 2007 layer and Southern California Association of Governments (SCAG) 2001 layer, were merged to create a coverage that spanned the extent of the study area (Figure 3).

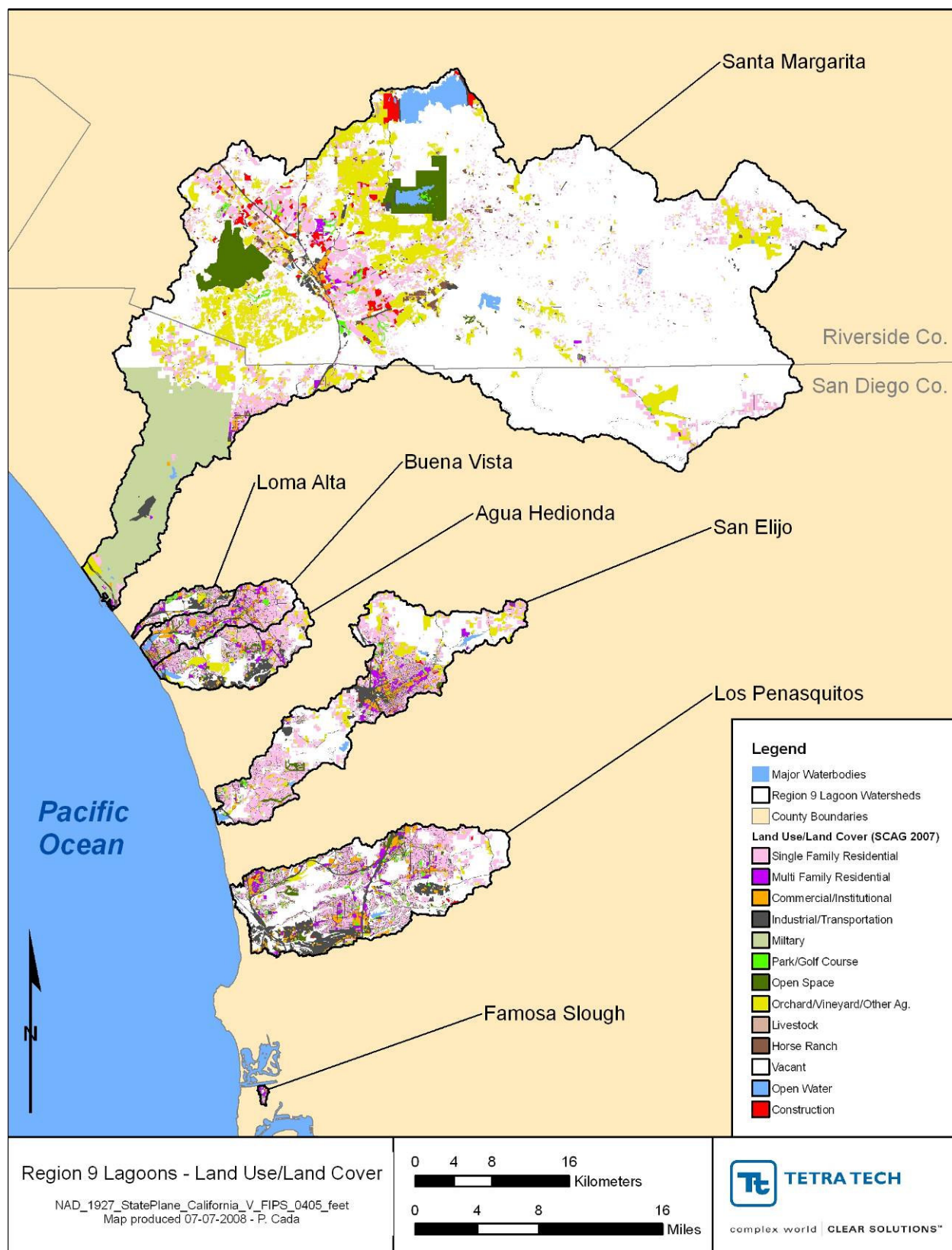


Figure 3. Land Use and Land Cover within the Modeled Watersheds

SANDAG land use data was originally developed specifically for the County of San Diego as a tool to assist the planning and management of urban development. Because it was developed specifically for the San Diego region it was used as the basis for the composite GIS data layer. SCAG land use data was used to provide coverage of the northern portion of the study area beyond the extent of the SANDAG data.

SCAG land use data layers were developed for multiple counties in the southern California region. Data for Riverside and Orange counties were used to augment the existing SANDAG data. The descriptions of land use parcels in the SANDAG and SCAG data were compared and based on the comparison, SANDAG land use codes were assigned to corresponding SCAG land use parcels. The updated SCAG and original SANDAG land use data were merged to create a unified coverage for the entire study area. Below is additional information related to the land use layers used in the TMDL study and where they can be obtained.

SANDAG

The SANDAG land use GIS data layer is based on the interpretation of current and historic aerial imagery, SanGIS landbase (i.e., parcels) and miscellaneous ancillary data sources. SANDAG's Land Layers are created for use in the Regional Growth Forecast to distribute projected growth for the San Diego region to suitable subareas in the region. These land layers include existing land use, planned land use, land ownership, land available for development, and lands available for redevelopment and infill. The land layers inventory is updated when new information is available.

Many of these data sets are built from the San Diego Geographic Information Source (SanGIS) land base. The land use information has been updated continuously since 2000 using aerial photography, the County Assessor Master Property Records file, and other ancillary information. The land use information was reviewed by each of the local jurisdictions and the County of San Diego to ensure its accuracy.

Although agricultural lands are included in the inventory, they have not been systematically maintained or updated since the mid 1990s. The land use inventory only has agricultural land use change when the land becomes developed or urbanized. New agricultural lands have not been systematically added to the inventory.

SCAG

The SCAG land use GIS data layers for Riverside and Orange counties in California are available through the Southern California Association of Governments Web Accessible Geodata Search (WAGS). The land use descriptions of the mapped parcels were developed by Aerial Information Systems, Inc. as a Modified Anderson Land Use Classification in 1993. Land use classifications have been updated on an ongoing basis, most recently in 2001.

2.3 REFINEMENTS TO HYDROLOGY

Each subwatershed representing a direct tributary to a lagoon is represented with a single terminal stream and a series of upstream watersheds (hereby referred to as tributary subwatersheds). Streams are assumed to be completely-mixed, one-dimensional segments with a trapezoidal cross-section. To route flow and pollutants, development of rating curves is necessary. Whenever detailed geometry was not available, rating curves were developed for each stream using Manning's equation and stream physical data. Required stream data include slope, Manning's roughness coefficient, and stream dimensions, including mean depths and channel widths. Where stream dimensions were not available, they were estimated using regression curves that relate upstream drainage area to stream dimensions.

For the Santa Margarita watershed, HEC flood profile models are available for the mainstem, and have been used to further refine the representation of channel dimensions and the functional relationships between volume, stage, and discharge for each reach. In addition, there are known deficiencies in the

existing model representation of impoundments, diversions, and water releases in the Santa Margarita River, which have been corrected and improved based on best available data.

The LSPC WATER module (water budget simulation for pervious and impervious land segments), which incorporates algorithms derived from the PWATER and IWATER modules of HSPF, is used to represent hydrology for all pervious and impervious land units. This requires designation of key hydrologic parameters associated with infiltration, groundwater flow, and overland flow. Available soils data serve as a starting point for designation of infiltration and groundwater flow parameters. Hydrology parameter values are then refined through the hydrologic calibration process.

As mentioned above, there are regional calibrated values for hydrologic parameters in the model established in the prior modeling. A retrospective evaluation is being conducted of these parameters, and refinements made as necessary.

2.3.1 Dams, Diversions, and Discharges

Among the watersheds addressed in this effort, the Santa Margarita River watershed is the largest and most complex. As a result, the Santa Margarita model (and a few of the other models) must address a number of issues that are of little importance to many of the smaller watersheds, such as the presence of major dams and diversions, as well as point source discharges.

The Santa Margarita watershed contains three major reservoirs, along with various other water management structures. The reservoirs – although filled primarily with imported water from the Colorado River – intercept flow and pollutant loads from the upstream drainage area. They alter hydrology and trap much of the sediment and sediment-associated pollutant load from upstream. Further, the water that is released from these structures is primarily imported water, and so does not reflect the simulated water quality from the upstream drainage area.

A major diversion is also present on the mainstem of the Santa Margarita River at USMC Camp Pendleton. This diversion has a significant effect on flow in the lower portion of the river, and also diverts a portion of the pollutant load present upstream in Lake O'Neill.

The effects of these structural interventions on the river must be included in the model to produce reliable results. Therefore, significant effort was expended in working with local entities to obtain available data to properly characterize the operation and impact of these structures, particularly in regard to how they impact stormflow runoff. This results in a model that correctly accounts for this portion of the water balance. It should be emphasized, however, that the model is not intended or appropriate for use in resolving litigated water rights disputes in the Santa Margarita.

Several other watersheds also contain impoundments. These have not yet been fully documented and implemented in the models developed for Phase I of the project.

The next six subsections discuss each of the major structural interventions in the Santa Margarita watershed. The seventh subsection contains notes on the impoundments present in other watersheds covered by the model.

2.3.1.1 Diamond Valley Lake

Diamond Valley Lake was completed in November 1999 on Domenigoni Valley Creek to store imported Colorado River water from the San Diego Canal, and is said to be the largest earthwork project in the history of the United States. It is owned and operated by Metropolitan Water District and provides a storage capacity of 800,000 AF. The lake also intercepts flow from a small upstream drainage area.

The permit for construction of the lake requires that native flows from the watershed be released downstream. Only controlled releases have occurred during the lake's history. The Water Systems

Operations group at Metropolitan Water District provided information on releases from Diamond Valley Lake at the request of the San Diego Regional Board. As shown in Figure 4, significant releases occur infrequently.

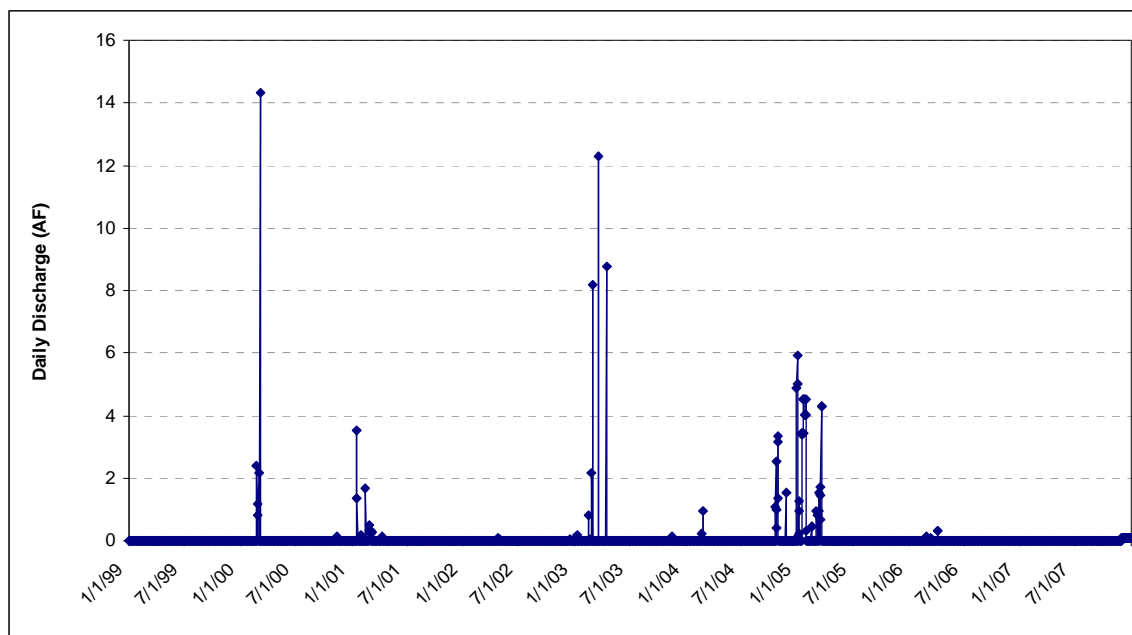


Figure 4. Daily Releases from Diamond Valley Lake

Within the model, Diamond Valley Lake intercepts flow from reaches 626-628 and discharges water to Reach 625 at the Goodhart Canyon Retention Basin. Accordingly, the model linkage between Reach 626 and Reach 625 was disconnected and replaced by the measured and estimated releases from Diamond Valley Lake for the period after 1 Oct. 1999 (specified as an External Source), while the simulated outflow from reach 626 is used prior to that date. The switchover is automated through use of HSPF Special Actions. At this time, water quality associated with releases from Diamond Valley Lake has not yet been incorporated into the model. The water quality in the releases is anticipated to reflect San Diego Canal water quality, with little influence from the local drainage. The loads in releases can be added to the model by specifying the appropriate linkages to reach loading (as a multiplier on flow) in the External Sources block.

2.3.1.2 Lake Skinner

Lake Skinner, on Tualota Creek, is operated by Metropolitan Water District. Lake Skinner is located at the foot of Bachelor Mountain in the Auld Valley, approximately 10 miles northeast of Temecula. The lake was created in 1973 and expanded in 1991, with a current capacity of 44,200 acre feet. The lake's primary function is to store Colorado River water from the San Diego Canal and feed the Robert A. Skinner filtration plant, which provides treated water to 2.5 million people; however, it also intercepts upstream flows on Tualota Creek. Operation of the reservoir in regard to water rights is governed by a Memorandum of Understanding and Agreement dated 12 Nov. 1974 and updated in 2004. Among other things, this requires that releases "to Tualota Creek will be made at rates similar to those which would have occurred in the absence of the Reservoir." The actual manner in which these releases must be made is governed by a detailed set of rules.

The Water Systems Operations group at Metropolitan Water District provided information on daily releases from Lake Skinner at the request of the San Diego Regional Board (Figure 5).

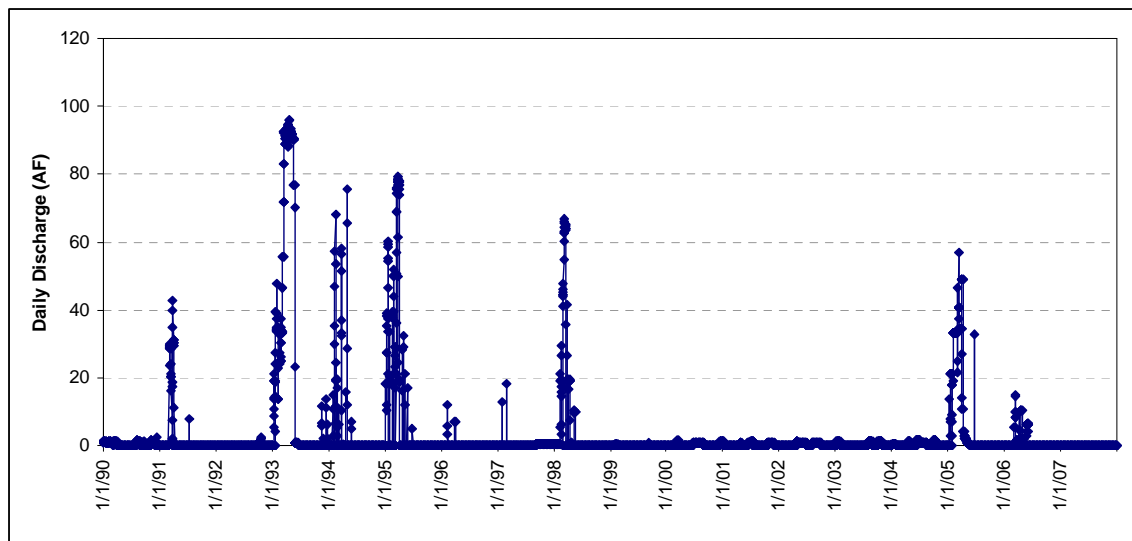


Figure 5. Daily Releases from Lake Skinner

Within the model, Lake Skinner intercepts flow from reaches 634-637 and discharges from the dam to Reach 633. Accordingly, the model linkage between Reach 634 and Reach 633 was disconnected and replaced by the measured and estimated releases from Lake Skinner. At this point, water quality associated with releases from Lake Skinner has not yet been incorporated into the model. Water quality of these releases is likely predominantly associated with the imported water from the San Diego canal; however, there may also be some noticeable contribution from the local watershed during high flow periods, so this would best be based on measured water quality at the Skinner filtration plant. As with Diamond Valley, loads in Lake Skinner releases can be input into the model by multiplying the flow time series by either constant or time varying constituent concentrations.

2.3.1.3 Vail Lake

Vail Lake, an impoundment on Temecula Creek 15 miles east of Temecula, was created in 1948 by the owners of Vail Ranch and has been operated by Rancho California Water District (RCWD) since 1978. The lake has a storage capacity of 51,000 acre feet and, unlike Diamond Valley and Lake Skinner, is supplied by local runoff. Surface water stored in the lake is used to replenish local ground water.

Within the model, Vail Lake is located at Reach 643 and intercepts drainage from a large upstream area, consisting of reaches 643-670 and constituting most of the eastern portion of the watershed. RCWD provided monthly records of controlled releases, spillage, and diversion to recharge areas from 1948 to present. Discharge from Vail Lake is mostly by controlled release, and spillage over the dam occurs infrequently and has not occurred since March 1993 (Figure 6).

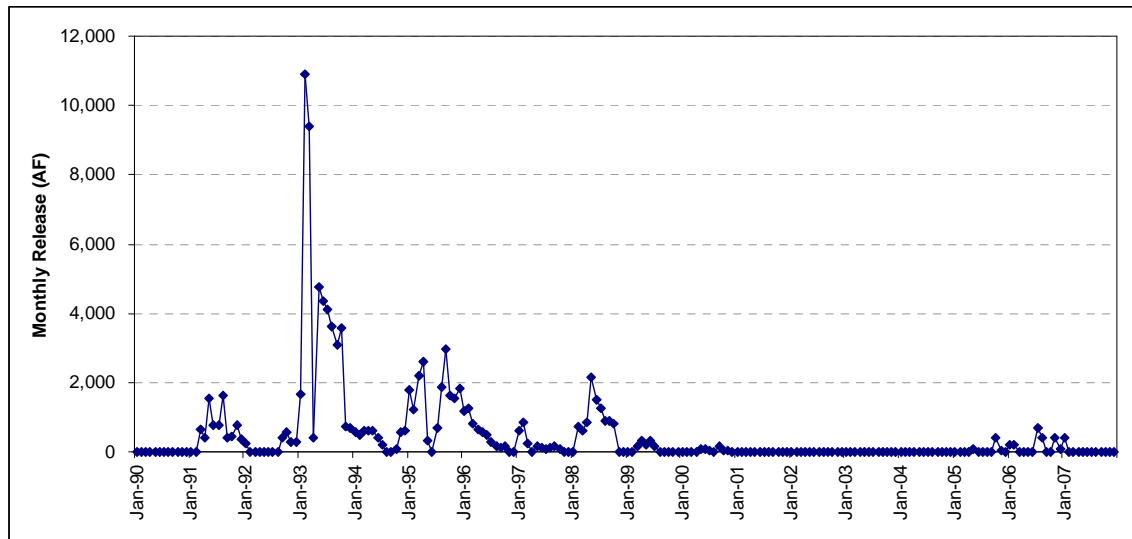


Figure 6. Monthly Releases from Vail Lake (Controlled Releases and Spillage)

Because most of the water downstream of Vail Lake is derived from controlled releases, the output is effectively decoupled from direct connection to simulated flows in the upstream watershed. Therefore, the model linkage from Reach 643 to Reach 642 was disconnected and replaced with the monthly sum of controlled releases and spillage. Water diverted to groundwater recharge is omitted from the total as much of this water is later recovered by pumping.

Unlike Diamond Valley Lake and Lake Skinner, water in Vail Lake is derived from the local watershed, and water quality in the outflow should reflect loading from the upstream watershed. The model is set up so that Reach 643 approximates the behavior of Vail Lake through a reservoir FTable. While this does not accurately predict the controlled releases, it will approximate the expected water quality in the lake. Therefore, downstream loads from Vail Lake can be simulated by multiplying the predicted concentration in Reach 643 times the measured release (not yet implemented in the model).

2.3.1.4 Rancho California Water District Discharges

RCWD has made two types of water releases to the Santa Margarita system. From December 1997 to October 2002 RCWD discharged reclaimed water to Murrieta Creek at the Santa Rosa Water Reclamation Facility at 26266 Washington Ave. in Murietta under a permitted demonstration project (NPDES permit CA0108821). The release point is located about 5 miles upstream from the confluence with Temecula Creek and is at the head of model Reach 619. Beginning in January 2003, RCWD has discharged raw Colorado River water to satisfy a water rights agreement. This discharge, which does not require a NPDES permit, takes place just south of the confluence of Murrieta Creek and Temecula Creek in the Santa Margarita River, just upstream of the USGS gage for the Santa Margarita River at Temecula. A new model routing reach was added to represent this point source discharge. Rancho California Water District provided data on water releases, including monthly totals for the reclaimed water discharges and daily flows for the raw water discharges. These are specified as external sources to the appropriate model reaches. Water quality has not been assigned to these releases at this time and needs further research.

2.3.1.5 Lake O'Neill: Camp Pendleton Diversions and Returns

Lake O'Neill, an impoundment of Fallbrook Creek on USMC Camp Pendleton, has a capacity of 1,400 AF (Figure 7). In addition to direct flow from Fallbrook Creek, USMC Camp Pendleton exercises an appropriative water right to divert water from the mainstem of the Santa Margarita via O'Neill Ditch

through use of a low head diversion dam. A larger portion of the diverted water is used for groundwater recharge purposes through spreading structures adjacent to the river channel. In an average year, groundwater pumping is about twice the amount of water infiltrated from recharge ponds, indicating that there is a net loss from the river to groundwater in this portion of the river (Stetson, 2001). Spillage from Lake O'Neill returns to the river.

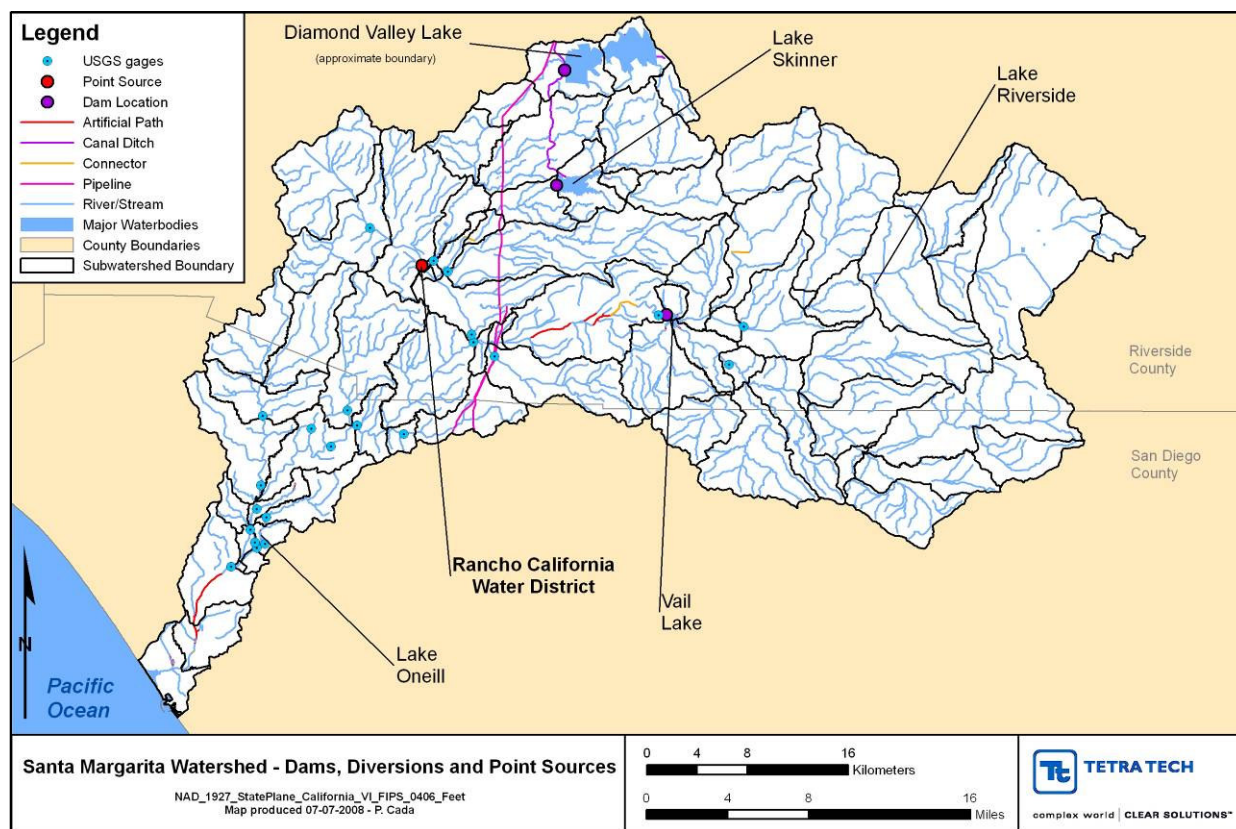


Figure 7. Dams, Diversions, and Point Sources – Santa Margarita River Watershed

2.3.2 Irrigation

Irrigation is an important component of the water balance in Southern California. Through changes in soil moisture storages, it affects storm runoff as well as baseflow.

The irrigation demand for the Santa Margarita model was calculated based on information presented in “A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California” (University of California Cooperative Extension, 2000). This guide recommends comparing daily precipitation to water demand to determine the amount of irrigation water needed.

Tetra Tech previously estimated hourly potential evapotranspiration (ET) for five zones based on CIMIS data (Section 2.2.1.2). Hourly values were summed over each day to determine the daily potential evapotranspiration depth in inches. To convert the potential evapotranspiration to the water demand for a specific crop or plant, a crop specific coefficient is multiplied by the potential evapotranspiration. University of California Cooperative Extension (2000) suggests a crop coefficient of 0.6 for lawns planted with warm season grasses and 0.65 for agricultural citrus production. For the purposes of this

analysis, Tetra Tech used one crop coefficient of 0.65 to estimate the daily water demand for residential and commercial lawns and agricultural areas.

The difference between daily water demand and daily precipitation was calculated for each day. If precipitation exceeded water demand, then the irrigation demand was set to zero. Precipitation was used to offset water demand from the following days until all of the precipitation was lost from the system. To estimate the amount of irrigation water applied, University of California Cooperative Extension (2000) suggests dividing the irrigation demand by the efficiency of the irrigation system. Tetra Tech assumed an efficiency of 80 percent for both the lawn and agricultural irrigation systems to estimate the depth of irrigation water applied.

Finally, the irrigation water applied was added to the water balance in the HSPF simulation. The daily amount applied was assumed distributed evenly over time.

The LSPC models also use demand-based irrigation using the ET time series. The implementation of the irrigation module will occur in Phase II.

2.3.3 HEC-RAS Flood Elevation Models

Movement of sediment and sediment bound pollutants through stream networks, including transport, scour, and deposition rates, is determined by flow energy. LSPC/HSPF does not directly solve hydraulic equations for flow routing, but rather specifies information on the relationship between stage, discharge, and geometry through Functional Tables (FTables). The calculation of boundary shear stress from the FTable information is a key component of the simulation of sediment transport.

Information contained in the FTables is typically developed outside the HSPF model by hydraulic models that more accurately represent discharge-storage-surface area relationships of modeled stream reaches. As a result, the accuracy of the LSPC/HSPF model in representing hydrology and instream hydraulics (and thus pollutant load) depends primarily on the quality of the channel geometry and roughness data collected for the hydraulic model that is used to generate the FTables.

HEC-RAS models were obtained for the mainstem Santa Margarita – the largest basin covered in the current effort. In 2000, West Consultants, Inc. developed a HEC-RAS model of the Santa Margarita River from the confluence of Murrieta and Temecula creeks to its outlet at the Pacific Ocean. WEST Consultants used both new and existing cross section geometries (from previous models developed by Simons, Li and Associates (SLA) and Northwest Hydraulic Consultants (NHC)) to analyze the 5-, 10-, 50-, and 100-year flood events. The sources of the topographic data used to create the cross-section geometries are included in Table 4. Discharge values were determined at three gage locations using a frequency analysis. The station names, estimated discharge values and their associated river reaches are included in Figure 8. However, due to limited gage data (especially during large events) and the lack of hydraulic roughness calibrations, the HEC-RAS model developed by WEST and utilized by Tetra Tech in this study presents concern regarding the accuracy of the survey data and generated water surface profiles.

Table 4. Cross Section Data Sources (from Santa Margarita River – Final Report, WEST)

Cross-Sections	Creator	Topography	Method
0 – 20,620	Simons, Li & Associates	USACE, 1994	5-ft contour map
20,646 – 48,145	Northwest Hydraulic Consultants	Winzler & Kelly, 1998	Laser topography
49,580 – 54,830	Simons, Li & Associates	USACE, 1994	5-ft contour map
55,583 – 93,227	WEST Consultants, Inc.	Camp Pendleton, 1994	5-ft digital contour map

94,068 – 128,383	WEST Consultants, Inc.	SDCPW, 1986	5-ft digital contour map
128,883 – 154,453	WEST Consultants, Inc.	USGS, 1968	5-ft digital contour map

Figure 8. Model Discharges

Gage Name	River Stations	10-Year Discharge	10-Year Discharge	50-Year Discharge	100-Year Discharge
Temecula	119033 – 154453	7,200	14,000	29,000	35,000
Fallbrook	65441 – 116033	8,000	17,000	36,000	44,000
Ysidora	0 – 63402	8,000	17,000	37,500	46,000

2.3.3.1 Creating FTables from HEC-RES

HEC-RAS applications provide an excellent basis for creating the FTables at selected points within a stream network. The accuracy of the generated FTable is dependent upon the spacing and number of HEC-RAS cross sections throughout a stream network, as well as the accuracy of the measured flows used to correlate river stage to discharge. HEC-RAS can interpolate between cross sections if the gaps are relatively small, but large gaps can eliminate the usefulness of disconnected upstream sections for FTable generation. If several measured flows are provided with a HEC-RAS model (e.g., flows from the 10-, 50-, 100-, 500-year return periods), the HSPF modeler can interpolate additional flows using percent differences in order to complete enough points in an FTable. As previously mentioned, data from adjacent stream gages can also be used to establish flow profiles in HEC-RAS for a particular reach.

Tetra Tech developed 11 FTables from the HEC-RAS model along the Santa Margarita River (Table 5).

Table 5. Subbasins Along Santa Margarita River with HEC-RAS Generated FTables

Subbasin	River Station	Modeled Length (mi)	Change in Elevation (ft)	# of Cross Sections
601	0 – 8,910	1.7	3.9	17
602	8910 – 22,507	3.0	23.1	29
603	22,507 – 42,471	3.7	45.4	39
604	42,471 – 45,057	0.4	5.4	9
674	45,057 – 49,580	0.8	10.2	11
605	49,580 – 56,240	1.4	28.8	11
607	56,240 – 63,402	1.4	20.6	8
608	63,402 – 64,422	0.2	2.0	1
613	64,422 – 109,683	8.6	219.5	57
615	109,683 – 121,783	2.1	79.9	11
616	121,783 – 154,453	6.2	516.5	30

To use HEC-RAS to generate FTables, additional flow profiles were created for every flow change point along a modeled reach in order to account for lower flows and improve FTable accuracy. The existing HEC-RAS model already contained estimated flow profiles for four flood return periods (e.g., 5-, 10-, 50-, 100-yr storms); however, more flow profiles were needed to create an FTable. As a result, Tetra Tech calculated the mean percent change between every flow change point along the reach from the provided flow profiles. Tetra Tech subsequently assigned 9 flow profiles (ranging between base flow and the 500-yr event peak flow) to the most upstream cross section. Finally, downstream flows were calculated for each flow change point and flow profile using the mean percent flow change values.

For each flow profile, HEC-RAS models provide the following water surface profile outputs for FTable generation:

- Q Total – total flow in cross section (cfs)
- Length Wt – weighted cross section reach length based on flow distribution (ft)
- Max Chl Dpth – maximum main channel depth (ft)
- SA Total – cumulative surface area for entire cross section from the bottom of the reach (acres)
- Volume – cumulative volume of water in the direction of computation (acre-ft)

Each point (or flow profile) representing the discharge-storage-surface area relationship by computed FTable is thus a weighted average of channel stage and discharge that is based on the weighted cross section reach length within the entire modeled reach. Also included for each flow profile in the FTable are the cumulative surface area and water volume between the reaches' upstream and downstream cross sections.

Similar flood elevation models have not been obtained for other watersheds within the study area. Where such models are available they should be used to create FTables in cases where sediment transport is an important issue relative to use impairment.

2.3.4 Groundwater Interactions

An important feature of coastal streams in Southern California is interaction with groundwater. The major surface aquifers in this terrain are generally associated with alluvial valley fill, with little storage in upland areas. Within the alluvial valleys water in the streams may be lost to groundwater, and this loss is often enhanced by pumping. At some locations, the presence of impervious rock barriers causes groundwater to return to surface flow.

Groundwater interactions are of lesser importance for the prediction of storm runoff peaks, but still can have an important effect on the antecedent conditions in the channel that help determine the ultimate magnitude and erosive power of flood events. Consideration of groundwater interactions becomes crucial for simulating average and low-flow conditions.

The LSPC/HSPF model contains a groundwater component which generally describes contributions of shallow groundwater to base flow in headwater areas, plus a provision for loss to deep groundwater. It is not a sophisticated groundwater simulation model, and does not directly simulate losing or gaining interactions with stream segments. Typically, these effects must be determined externally and specified to the model.

MWD (2007) provides a summary of the significant alluvial groundwater basins within the Santa Margarita, as well as various other basins relevant to the current project (Figure 9). Within the Santa Margarita, there are two basins of major significance to simulation: the Temecula-Murrieta basin and the Lower Santa Margarita basin.

The Temecula-Murrieta groundwater basin occupies the area between Temecula and Murrieta above the headwaters of the Santa Margarita proper. Rancho California Water District produces significant amounts of water from wells in this basin. Much of this water is derived from artificial recharge with untreated imported water; however, it is also evident from the gage records that streams crossing this basin lose flow to groundwater. At the downstream end of the basin, flow resurfaces near the head of the Santa Margarita gorge, and groundwater discharge supports the perennial streamflow observed in this reach.

The lower Santa Margarita groundwater basin is primarily located in the area along the mainstem downstream of the confluence with De Luz Creek, with a total storage capacity of about 69,200 AF, of which 28,700 AF is usable for water production. As noted above in the discussion of Camp Pendleton, there is significant recharge to the aquifer from surface water in this area, as well as production from wells. This undoubtedly results in a situation in which the river loses water to groundwater, in addition to the intentional diversions; however, the recharged water may also flow back into the river when the water table rises. Flow from this basin may also re-emerge to the surface in the Ysidora Narrows area.

The Santa Margarita Watermaster provides an annual accounting of inputs, outputs and storage in the groundwater basins of the Santa Margarita (SMR Watermaster, 2007), which can be used to obtain a rough balance of interactions with surface water. A groundwater model of the Murrieta-Temecula basin has been completed on behalf of Rancho California Water District 2003, but does not appear to be publicly available.

A relatively high level of knowledge has been developed for the Santa Margarita watershed groundwater basins, in part because of ongoing water rights issues and court orders controlling disposition of water in the system. Much less appears to be known about several of the other relevant groundwater basins, and some of the knowledge that is available may be considered proprietary.

An important issue for the next phase of model development will be the extent to which groundwater interactions are included in the model. Even for a model focus on wet weather runoff only, some approximate representation of major losing and gaining reaches needs to be incorporated. At a minimum, these can be represented as constant outflow demands (to represent losing reaches) and seasonally constant inputs to reaches based on available knowledge. Where detailed groundwater models are available it may be possible to specify detailed time series to characterize these interactions in the surface water model.

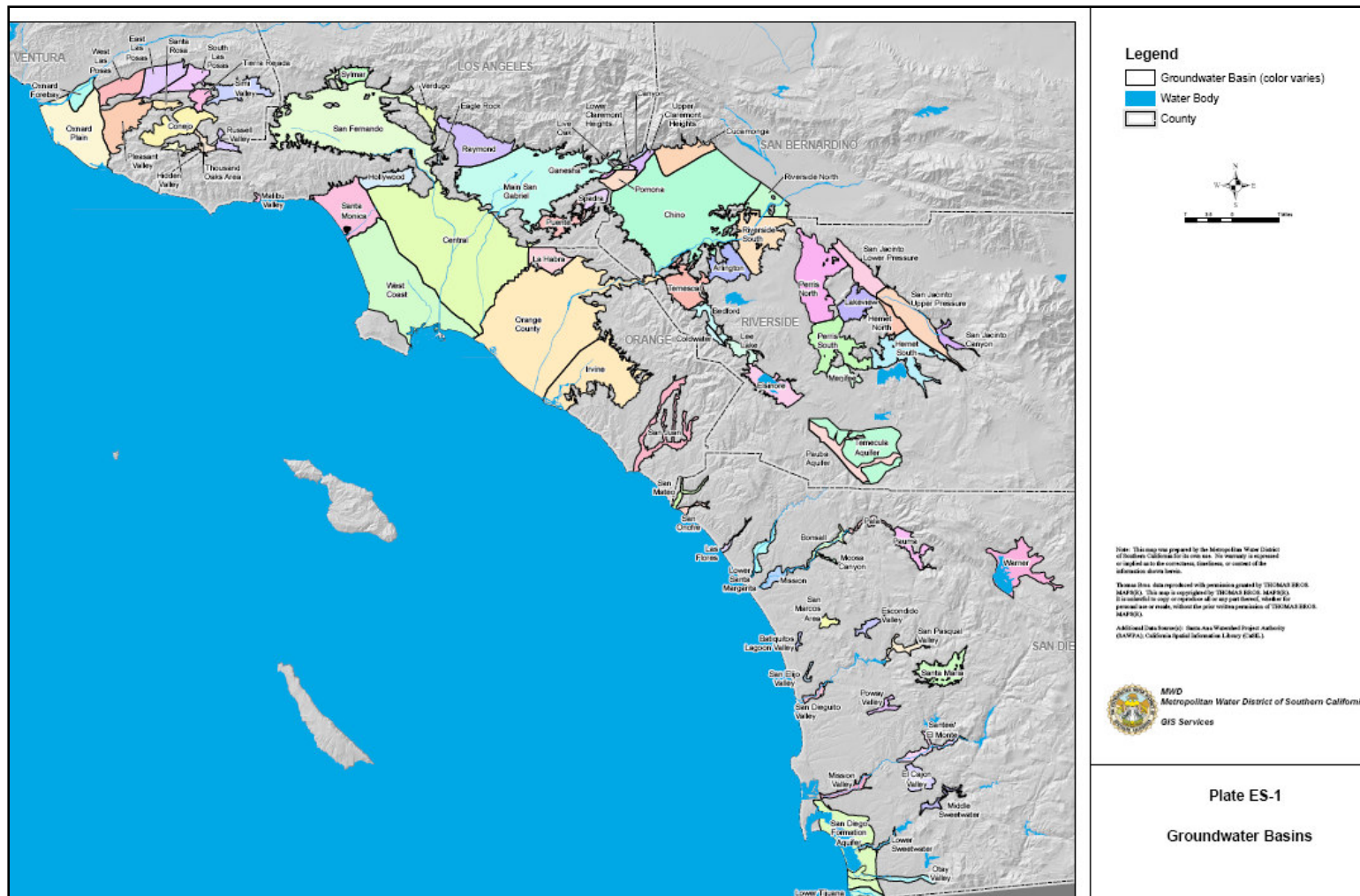


Figure 9. Groundwater Basins of the Southern California Coastal Region (from MWD, 2007)

2.3.5 Hydrologic Recalibration Status

Previous work for the Bacti-I models included initial calibration for wet weather hydrology for gaged watersheds in the San Diego Region (San Diego Water Board, 2007). Regional calibration parameters derived from calibration and validation at eleven streamflow gages were used as input to the Bacti-I and Bacti-II models. In the current study, these regionally-derived parameters were reviewed to determine if further refinement was necessary. In addition, new flow data being collected at previously ungaged watersheds and an extension of the simulation period, both of which will be completed and implemented in Phase II, provide an opportunity to refine the hydrologic calibration.

A significant focus of the current testing was for the Santa Margarita watershed. Santa Margarita is the largest of the seven watersheds and has a complex mix of impoundments, diversions, groundwater interactions, and imported water which have a significant effect on hydrology in the basin. An initial application of the regional parameters to other parts of the watershed suggested that additional refinement was necessary due in part to the aforementioned characteristics affecting hydrology.

Three gages used to develop the original regional calibration parameters are located in the Santa Margarita watershed: Temecula Creek near Aguanga, Santa Margarita River (SMR) at Ysidora, and SMR at FPU Sump near Fallbrook. Additional review of hydrologic simulation is recommended at several other gages throughout the watershed to support a robust, local calibration. Nine additional gages located in the watershed were evaluated for use in hydrologic recalibration (Table 6). Two additional gages were excluded due to lack of data: Deluz Creek near Fallbrook and Wilson Creek above Vail Lake.

Table 6. Candidate Hydrologic Calibration Gages in the Santa Margarita Watershed

USGS Gage #	Name	DSN in .wdm file	Comments
11042400	Temecula Creek near Aguanga	6007	Calibrated in Bacti-I
11046000	SMR at Ysidora	6010	Calibrated in Bacti-I
11043000	Santa Margarita River at FPU Sump nr Fallbrook	6009	Calibrated in Bacti-I
11044000	SMR nr Temecula	6009	
11044800	Deluz Crk nr Deluz	5000	
11044900	Deluz Crk nr Fallbrook	5001	Dry large periods of time and significant data gaps
11042631	Pechanga Crk nr Temecula	5002	
11044250	Rainbow Crk nr Fallbrook	5003	
11044350	Sandia Crk nr Fallbrook	5004	
11042900	Santa Gertrudis Crk nr Temecula	5005	
11042800	Warm Springs Crk nr Murrieta	5006	
11042490	Wilson Crk above Vail Lake	5007	Discontinued in 1994

The hydrologic calibration at the remaining seven gages in the Santa Margarita was reviewed using simulations from 1990 through 2006 but focused on 2000 through 2006. An initial review of the results of simulation using the regional calibration parameters suggested the need for refinement. A series of

linked spreadsheets was created for this purpose. The first (LZSN&INFILT v3b.xls) provides the initial hydrologic parameters by soil hydrologic group. Scaling factors were applied to adjust LZSN and INFILT, primarily, though additional testing and adjustment was conducted with other parameters as well. This spreadsheet is linked to another spreadsheet (Schematic_newLU v3b.xls) that formats the parameters for the input file to HSPF. This information is automatically formatted for pasting to the HSPF .uci file.

Initial results from three of the additional gages are presented in Figures 10-12. The time series comparison reveal some deficiencies in fit. For example, there appears to be a change in hydrologic response beginning in 2005 (c.f. Figure 10) that needs to be investigated. In addition, adjustment to the low flow simulation will likely be needed including revisiting the irrigation module. Additional parameter modification should be pursued in Phase II once the model time period has been extended through 2008 and additional data collection is complete.

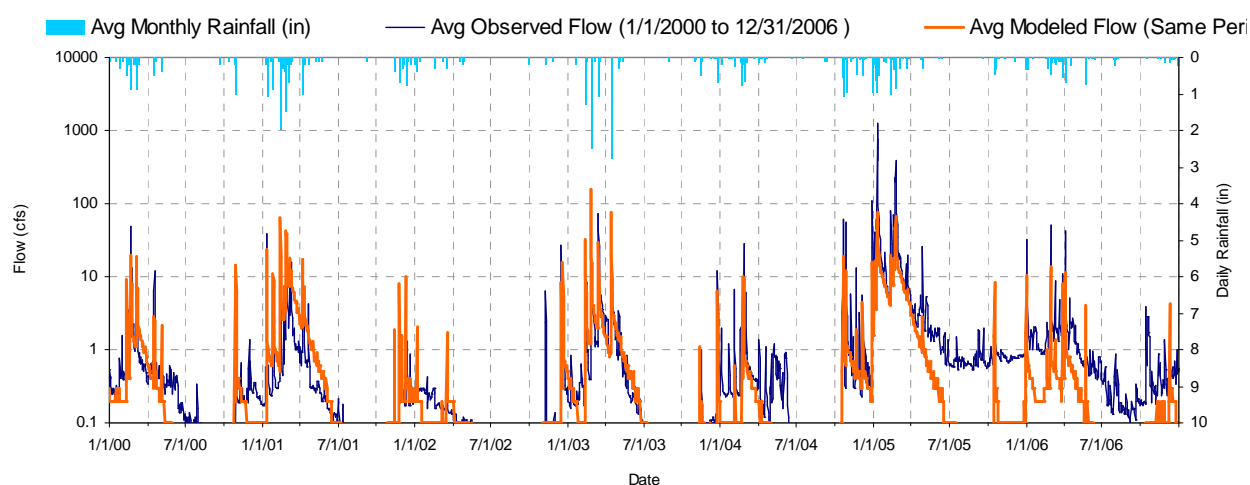


Figure 10. Comparison of Observed and Simulated Flows at USGS 11044250 RAINBOW C NR FALLBROOK

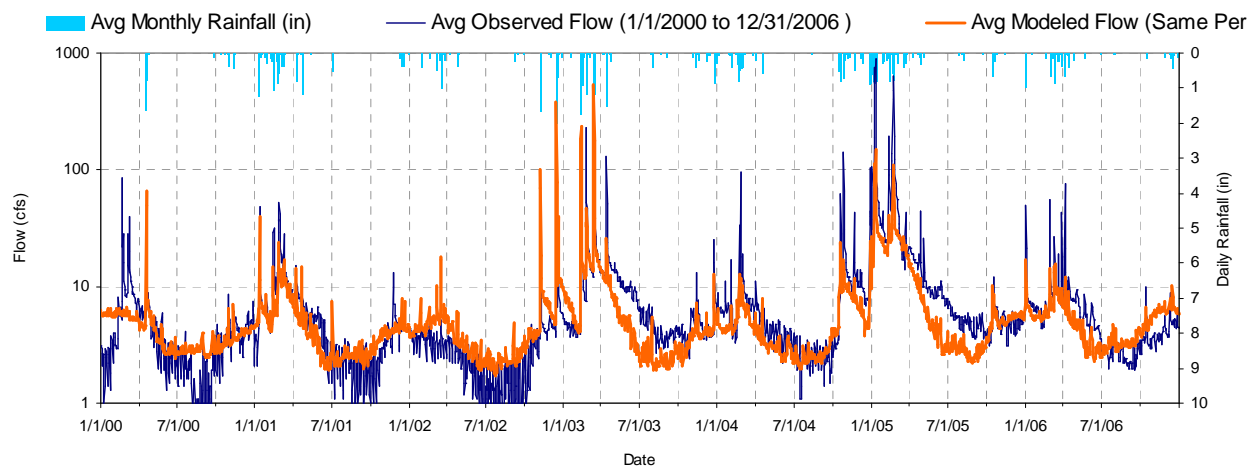


Figure 11. Comparison of Observed and Simulated Flows at USGS 11044350 SANDIA C NR FALLBROOK

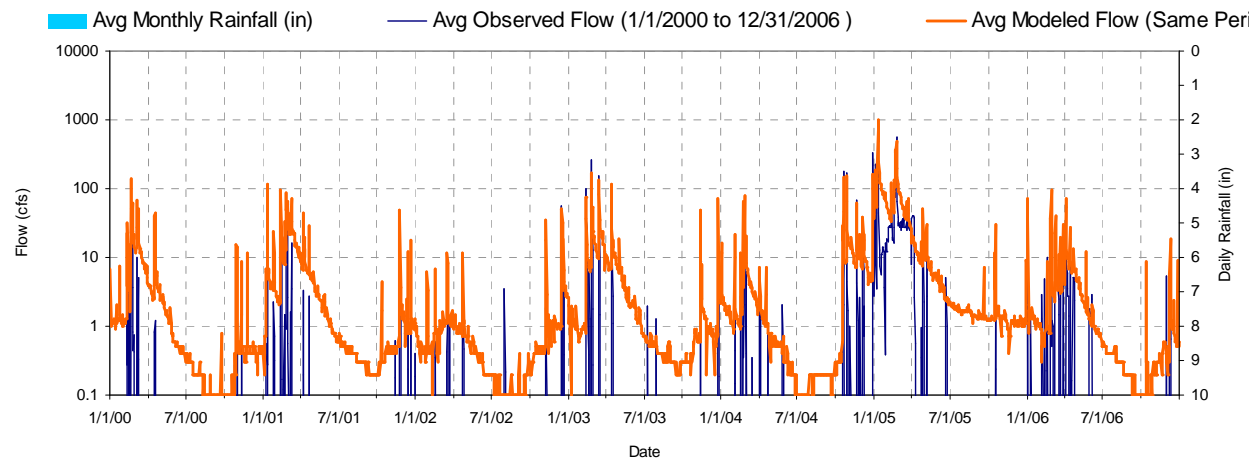


Figure 12. Comparison of Observed and Simulated Flows at USGS 11042900 SANTA GERTRUDIS C NR TEMECULA

In addition to the focus on Santa Margarita, parallel work in the Agua Hedionda watershed was conducted under a separate project being conducted by the City of Vista, California. Approximately one year of continuous flow data collected in the watershed on Agua Hedionda Creek and El Camino Real Bridge was used to test and refine the LSPC model calibration in Agua Hedionda. Information on model configuration and calibration gathered during this process can be incorporated into the TMDL models in Phase II.

Additional refinement of the hydrologic calibration will be pursued in all of the watersheds in Phase II.

2.4 POLLUTANT LOADING

The primary pollutants represented in the watershed model to estimate loadings to the receiving water model include bacteria, total nitrogen (TN), total phosphorus (TP), BOD, suspended sediment, and TDS.

In-stream flow calculations will be made using the HYDR (hydraulic behavior simulation) module in LSPC, which is identical to the HYDR module in HSPF. In-stream pollutant transport will be performed using the ADVECT (advective calculations for constituents) and GQUAL (generalized quality constituent simulation) modules.

Pollutant loading processes for all pollutants in the watershed model are represented for each land unit using the LSPC QUAL module (simulation of quality constituents for pervious and impervious land segments), which incorporates algorithms derived from the PQUAL and IQUAL modules of HSPF. This module simulates the accumulation of pollutants during dry periods and the washoff of pollutants during storm events. Initial values for parameters relating to land use-specific accumulation rates and buildup limits are derived from literature. These values will be refined through the water quality calibration process. Application of the sediment modeling routine will be considered to represent TSS (as opposed to the QUAL routines).

The Bacti-I modeling established a set of initial parameters for bacterial simulation. The starting point for the sediment simulation was specified to be the set of regional sediment parameters currently being developed by the Southern California Coastal Water Research Project (SCCWRP). These parameters are primarily appropriate to urban land uses with altered urban soils. For the more rural areas, Tetra Tech

developed a method to extrapolate SCCWRP results, taking into account local differences in topography and soil characteristics.

Parameterization of the nutrient transport model was initialized with the parameters established for the LSPC application to the San Jacinto watershed (Lake Elsinore and Canyon Lake). The parameters calibrated for this model have performed well in that region; however, their performance needs to be reevaluated relative to monitoring data available for the lagoon watersheds.

2.4.1 Sediment Simulation

SCCWRP is developing regional modeling parameters for the Southern California area. While appropriate for urban sites with disturbed soils, this effort has focused on urban developed land and covers a variety of parameters, including sediment. SCCWRP has provided several draft revisions of their proposed regional sediment parameters but a peer-reviewed report has not yet been issued. The SCCWRP approach was evaluated as a basis for the lagoon TMDL models.

2.4.1.1 SCCWRP Regional Sediment Model

The SCCWRP regional sediment approach assumes that the HSPF pervious land sediment erosion parameters are a function of land use and are otherwise the same for every site. This ignores any differences in soil characteristics, slope, or rainfall power between sites. Potential extension of the method to a wider geographical area can only exacerbate this problem. As shown below, theoretical considerations suggest a way to modify and scale the assigned parameters to account for inter-site differences.

Theoretical Basis

The LSPC/HSPF model does not use the Universal Soil Loss Equation (USLE) for sediment simulation. However, some of the parameters used in HSPF are similar to those in the USLE. The SSURGO and STATSGO soils databases provide a number of USLE parameter estimates by soil type, and these can be used to set initial parameter values – ensuring relative consistency between the HSPF and USLE approaches.

HSPF calculates the detachment rate of sediment by rainfall (in tons/acre) as

$$DET = (1 - COVER) \cdot SMPF \cdot KRER \cdot P^{JRER}$$

where *DET* is the detachment rate (tons/acre), *COVER* is the dimensionless factor accounting for the effects of cover on the detachment of soil particles, *SMPF* is the dimensionless management practice factor, *KRER* is the coefficient in the soil detachment equation, *JRER* is the exponent in the soil detachment equation, and *P* is precipitation in inches. Actual sediment storage available for transport (*DETS*) is a function of accumulation over time and the reincorporation rate, *AFFIX*. The equation for *DET* is formally similar to the USLE equation (Wischmeier and Smith, 1978),

$$RE \cdot K \cdot LS \cdot C \cdot P,$$

where *RE* is the rainfall erosivity, *K* is the soil erodibility factor, *LS* is the length-slope factor, *C* is the cover factor, and *P* is the practice factor.

USLE predicts sediment loss from one or a series of events at the field scale, and thus incorporates local transport as well as sediment detachment. For a large event with a significant antecedent dry period, it is reasonable to assume that $DET \approx DETS$ if *AFFIX* is greater than zero and the transport capacity of the previous large rainfall event was sufficient to remove most of the detached sediment. That is, storm sediment yield is primarily a result of the current event. Further, during a large event, sediment yield at

the field scale is assumed to be limited by supply, rather than transport capacity. Under those conditions, the USLE yield from an event should approximate *DET* in HSPF.

With these assumptions, the HSPF variable *SMPF* may be taken as fully analogous to the USLE *P* factor. The complement of *COVER* is equivalent to the USLE *C* factor (i.e., $(1 - COVER) = C$). This leaves the following equivalence:

$$KRER \cdot P^{JRER} = RE \cdot K \cdot LS.$$

The empirical equation of Richardson et al. (1983) as further tested by Haith and Merrill (1987) gives an expression for *RE* (in SI units of MJ-mm/ha-h) in terms of precipitation:

$$RE = 64.6 \cdot a_t \cdot R^{1.81},$$

where *R* is precipitation in cm and *a_t* is an empirical factor that varies by location and season. This suggests that the exponent *JRER* on *P* should be 1.81, yielding

$$KRER = \frac{RE \cdot K \cdot LS}{P^{1.81}}.$$

This further implies a linear relationship of *KRER* to *K* and *LS*, as rainfall raised to the 1.81 power appears in both the top and bottom of the equation:

$$KRER = G \cdot K \cdot LS,$$

where *G* is a parameter that accounts for unit conversion and also includes the *a_t* factors from the Richardson model.

For areas in which the *a_t* parameters of the Richardson model have been developed (a laborious process), the value of *G* can be evaluated explicitly, yielding a quantitative theoretical relationship between *KRER* and the USLE *K* and *LS* parameters.

The *a_t* parameters do not appear to have been derived for the Los Angeles region. Isoerodent maps of *RE* have been developed for California (Renard et al., 1996). Values of *RE* vary across short differences in this area (Figure 13). However, *RE* is a function of both *a_t* and precipitation amount. In the Los Angeles region, the variability in *RE* appears to be primarily a result of storm volume (see Figure 14), suggesting that the *a_t* factor may have limited variability in this region. If so, the isoerodent map is driven primarily by rainfall amount and yields little information on the value of *KRER*.



Figure 13. Isoerodent Map of Southern California (ft-tonf/(ac-hr-yr); Renard et al., 1996)

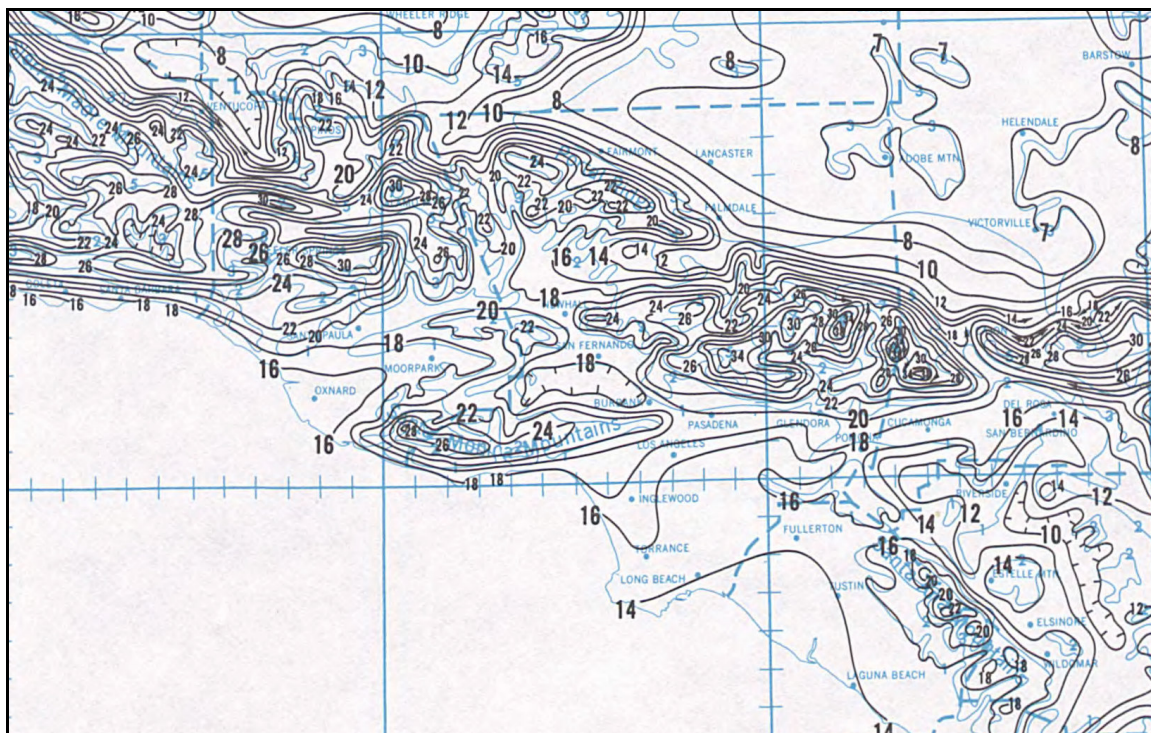


Figure 14. 2-yr 6-hr Precipitation in the Los Angeles Area (NOAA, 1973)

The approximate expected magnitude of *KRER* can be obtained with an assumption of the value of α_i . *RE* is converted from the SI units of MJ-mm/ha-h-yr to English units of 100s of ft-ton-in/ac-hr-yr (used in the development of USLE *K* factors and consistent with the English units in HSPF) by a factor of 0.05875. In addition, the ratio of precipitation factors (in cm and in) must be converted to a common basis by multiplying by 2.54^{1.81}. This suggests that the value of *G* should be about 20.51 α_i . Values of α_i are typically on the order of 0.15 – 0.20. A value of α_i of 0.15 would suggest that *KRER* should be about 3.07 *K LS*, while α_i of 0.2 yields 4.1 *K LS*. For lower slope (1-5 percent) sites with slope lengths around 15 to 30 m, *LS* often evaluates to around 0.3, in which case *KRER* \approx *K*. This is consistent with the recommendations on sediment parameter setup for HSPF (USEPA, 2006) that a starting point for calibration is to set *KRER* equal to the USLE *K* value. However, it is obvious from the discussions above that higher values will be needed on higher slopes.

Tetra Tech extracted soil and slope parameters from both the STATSGO and SSURGO soils coverage. The USLE *K* factor is available directly from soil surveys, while the *LS* factor can be estimated from slope, using the expression of Wischmeier and Smith (1978):

$$LS = (0.045 L)^b \cdot (65.41 \sin^2 \theta_k + 4.56 \sin \theta_k + 0.065), \text{ where}$$

$\theta_k = \tan^{-1} (S/100)$, *S* is the slope in percent, *L* is the slope length (m), and *b* takes the following values: 0.5 for $S \geq 5$, 0.4 for $3.5 \leq S < 5$, 0.3 for $1 \leq S < 3$, and 0.2 for $S < 1$. Slopes were taken as the representative value from the soil unit. Finally, interpolated values of *RE* (in hundreds of ft-ton-in (ac-hr-yr)⁻¹) were obtained by superimposing the California isoerodent map figure (which is not available in geo-referenced form) on the site location map.

For many of the sites within the more urban portions of Los Angeles, SSURGO parameters are not available as the native soils are extensively modified. The STATSGO coverage does provide values at a coarser scale that combine multiple soil units, but these do not appear to be reliable, with many of the locations classified as predominantly sand with an extremely low *K* factor of 0.05.

SCCWRP provided locations (as points) for 25 of the small individual land use study sites. Of these, 19 are in urban areas where there is STATSGO but not SSURGO soils coverage. Information from the STATSGO-only sites does not appear sufficient to develop estimates of *KRER*; as noted above, many of these have extremely low *K* factors for the dominant component at the STATSGO scale. One of the remaining six sites presents a problem for analysis in that the soil representative slope is given as 50 percent; in reality, any soil present in this MUID would be on lower slopes, while slopes at 50 percent are likely to be bare rock.

SCCWRP Individual Land Use Sites

In the regional sediment approach, SCCWRP (Ackerman et al., 2004) originally proposed setting *KRER* at 0.35 for all sites. This has since been revised, and the current estimate is 0.23, again applied to all sites (email from Drew Ackerman, SCCWRP, to Jonathan Butcher, Tetra Tech, October 3, 2007). Either value is well within the range of “typical” values for *KRER* in HSPF applications of 0.15-0.45 (USEPA, 2006); however, assumption of a constant value of *KRER* across all sites is not theoretically justifiable, as shown above, if there are variations in soil erodibility (*K* factor) or slope.

For the six sites with identifiable parameters, the *K* factor varied from 0.2 to 0.55, while the representative slope values varied from 1 to 50 percent (with all but one less than 6 percent). After applying the methods described above, the resulting estimates of *KRER* have a median of 0.22 at an assumed α_i value of 0.15, and a median of 0.29 at an assumed α_i value of 0.20 – both of which appear to be in general agreement with the revised value proposed by Ackerman. (The summary is presented in terms of the median, rather than the mean, to avoid undue influence from the outlier site with a reported representative slope of 50 percent.) There is, however, substantial variability about this median value: excluding the site with 50 percent slope, estimated *KRER* values range from 0.10 to 0.35 at an α_i value of 0.2.

Summary and Recommendations

In sum, the revised SCCWRP estimate of the sediment detachment parameter *KRER* appears reasonable as a generalized estimate, particularly for urban areas where detailed NRCS soil coverages are not available. Comparison to the Richardson model of erosivity does suggest use of a value of 1.81, rather than 2, for the exponent *JRER*.

It is also clear that values of *KRER* should vary to reflect differences in soil erodibility and slope. For more rural areas in which accurate soil coverages and properties are available, *KRER* values should be adjusted to reflect these properties, using the methods described above. (For now, use of an a_r value of 0.2 would appear generally consistent with the generalized model fit. This could perhaps be improved by fitting the Richardson model to coastal Southern California precipitation records.)

Even within urban areas, estimates with the regional sediment model could likely be improved by adjusting for slope. As seen above, *KRER* should scale linearly with the *LS* factor. Thus, a generalized *KRER* value for an urban area could be scaled up or down by the ratio of the local *LS* to the representative *LS* for the watersheds used to establish the model calibration.

2.4.1.2 Soil Properties and Adjustments to Model

SSURGO Erosion Parameters

SSURGO soil data for San Diego, Orange and Riverside counties were utilized to calculate weighted *KRER* values for each land use and soil hydrologic group (HSG) within the San Diego region watersheds of interest. A weighted average of soil slope (*S*) and soil erodibility factors (*K*) was calculated for each soil map unit in ArcGIS using the NRCS Soil Data Viewer. The land use classification layer (which contained HSG values for each parcel) was subsequently intersected with both the aggregated slope (Figure 15) and *K* factor layers (Figure 16). In a spreadsheet program, slope and *K* factor values were subtotaled and area weighted for each land use classification and soil hydrologic group across the watershed. In order to calculate *KRER* values, length-slope (*LS*) factors were first calculated according to the Wischmeier and Smith (1978) equation.

A slope length (*L*) value of 15 meters was used for all *LS* calculations, and *LS* values were not allowed to exceed 5. This correction adjusts for the resolution of the DEM, as soils in very steep areas are primarily on small segments of lesser slope.

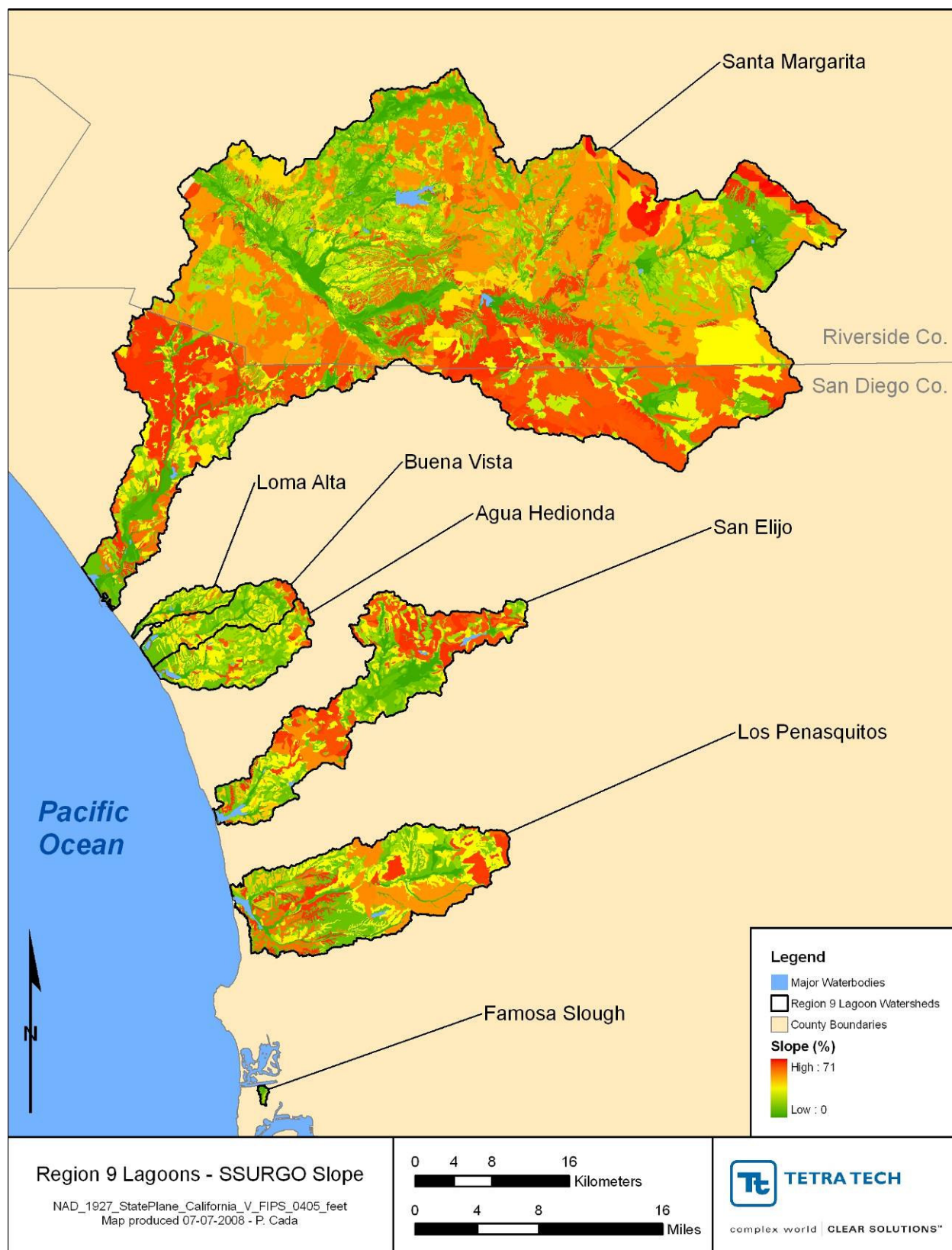


Figure 15. Percent Slope from SSURGO Dataset

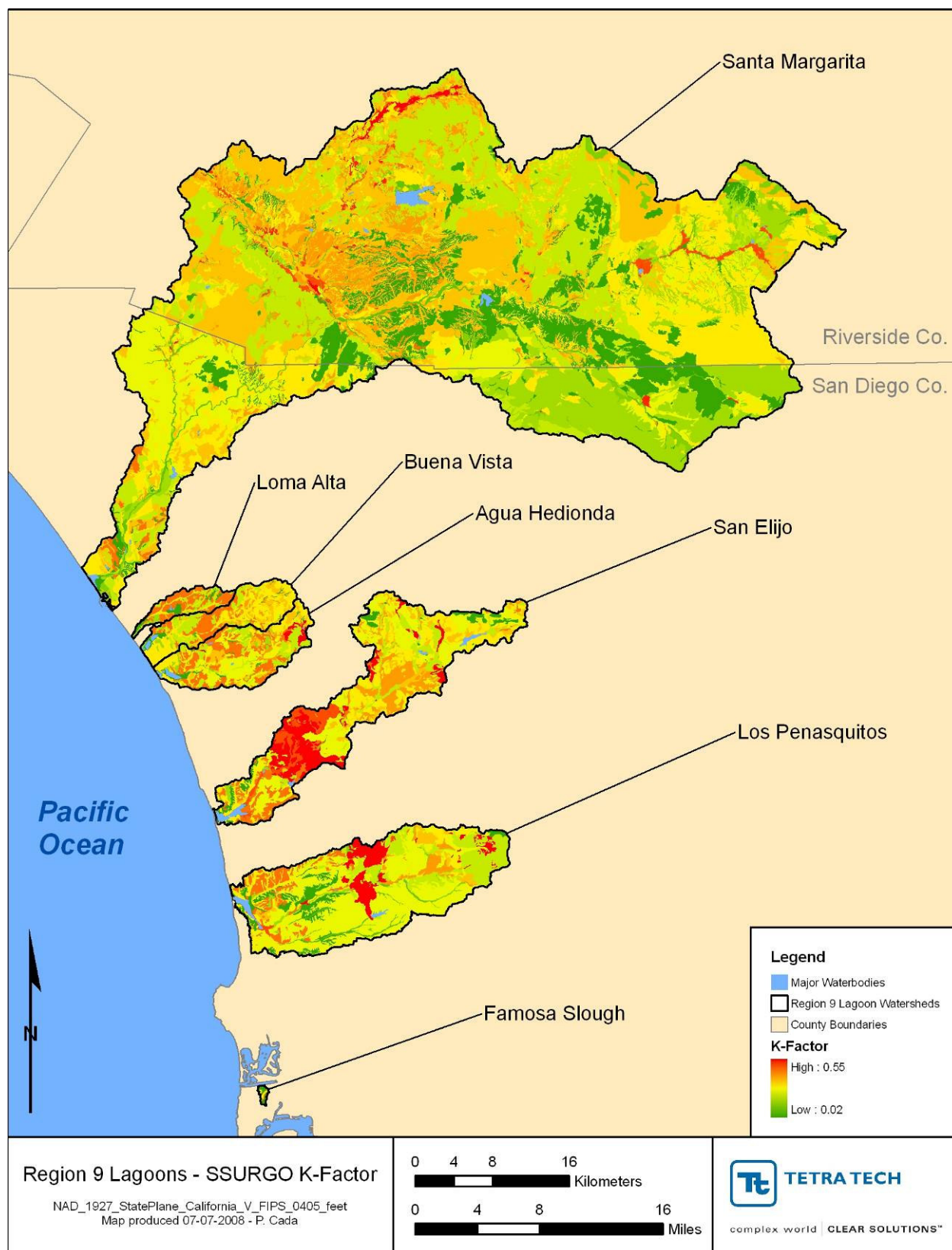


Figure 16. SSURGO Erosion Factor (K factor)

2.4.1.3 Santa Margarita Sediment Simulations

While the water quality calibration data for the model have not yet been received and the model has not been calibrated for sediment and water quality, information on sediment transport in the Santa Margarita is available from past studies. In particular, West (2000) conducted a detailed hydraulics and sedimentation study of the Santa Margarita mainstem and estimated mobile sediment volumes and loads for events of specific recurrence and average annual sums. This report provides a useful point of comparison for the simulation of sediment delivery from the Santa Margarita.

West estimated upland loads for the entire watershed using five different methods. Average annual results for upland loads from the different methods range from 1.23 to 5.57 tons/ac/yr; however, there is wide variability between loading rates for individual subbasins. West also analyzed delivered load in the mainstem using the HEC-6T model. This was not linked to the upland loading estimates; rather, loads were based on rating curves at inflow points to the mainstem. For the 1994-1998 calibration period, West estimated average annual delivery past the I-5 bridge just upstream of the estuary of about 44,000 tons/yr; however, the load is highly correlated to flow magnitude, and a single 25-year event was estimated to deliver 245,000 tons.

In its present uncalibrated state, the Santa Margarita HSPF model estimates sediment delivery to the estuary for 1994-1998 averaging 272,000 tons/yr. This is much higher than the West estimate, with differences likely primarily due to underestimation of sediment deposition and retention in the lower Santa Margarita alluvial valley. Most of the load occurs in a few larger events (Figure 17); however, the model also tends to predict throughflow to the estuary for periods in which the river channel is actually dry (because channel losses are not simulated). The detailed results contained in the WEST report should be used to help constrain the model when final calibration for sediment takes place.

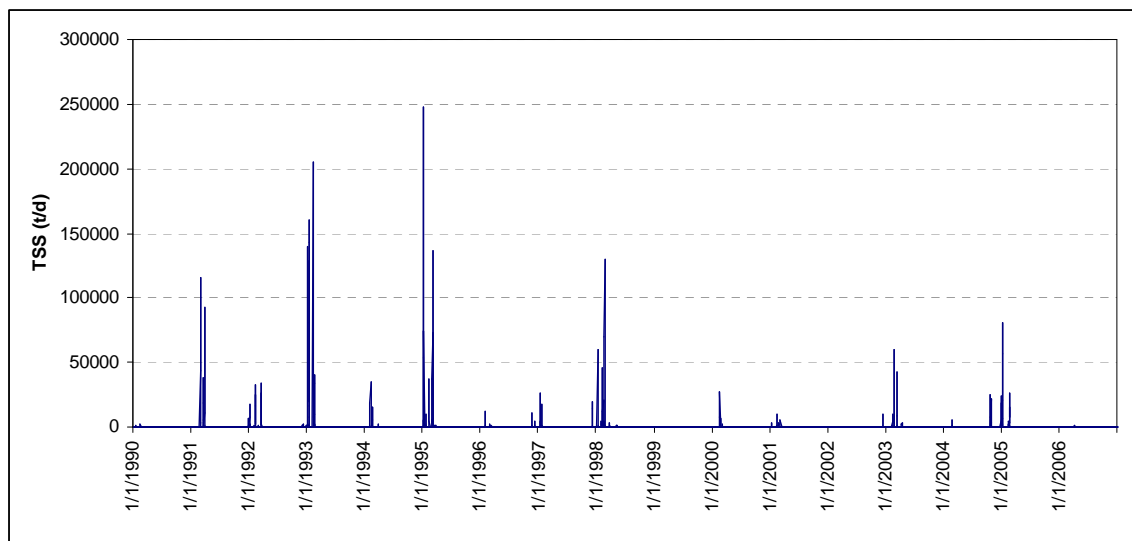


Figure 17. Current Uncalibrated Predictions of Daily Sediment Load to the Santa Margarita Estuary

2.4.2 Nutrient Simulation

The work plan for Phase I directed that the models were to be set up for nutrient simulation using parameter values developed for the San Jacinto TMDL model.

The San Jacinto (Lake Elsinore and Canyon Lake) implementation is set up for Total N and Total P. These constituents are simulated via buildup/washoff, plus interflow and groundwater concentrations. TN and TP are simulated as general quality constituents in the stream reaches, with decay coefficients assigned as follows: the decay coefficient is set at 0.25 day^{-1} for Total N (as well as individual N species) and 0.014 day^{-1} for Total P (as well as individual P species).

Calibration of the San Jacinto model is based on limited data. As stated in the San Jacinto TMDL report, “Water quality calibration adequacy was primarily assessed through review of time-series plots. Looking at a time-series plots [sic] of modeled versus observed data provided more insight into the nature of the system and was more useful in water quality calibration than a statistical comparison... Due to the relative lack of water quality monitoring data, statistical comparisons were not made.” In other words, the calibration consisted largely of a qualitative test that observed and simulated data cover approximately similar ranges. There were multiple stations that isolated different land uses, so there is some leverage to distinguish between land uses. Thus, the calibrated parameters in this application can only serve as an approximate starting point for other applications.

The land use categories for the San Jacinto model are derived from MRLC and Eastern Municipal Water District (EMWD), and do not exactly correspond with (or provide a one-to-one match to) those in the San Diego region models. The Urban category for San Jacinto has much lower imperviousness than similar categories in the San Diego region models, but this is acceptable since parameters are specified differently for the pervious and impervious fractions of this land use. Agriculture in the San Diego region models is spread over several categories (with different parameters) in the San Jacinto model, as is Open Space. The San Jacinto model land uses are compared to those in the San Diego Lagoons Model in Table 7.

Table 7. San Jacinto Model Land Uses and Correspondence to Lagoons Model Land Uses

San Jacinto LU	Includes	Percent Impervious	Corresponding San Diego Region Model Land Use
Urban	Commercial, Institutional, Industrial, Public Infrastructure	15%	1400 Commercial/Institutional 1500 Industrial/Transportation 1700 Parks/Recreation
High_Den_res	HDR	65%	1200 High Intensity Residential
Mobile_Trailor	Mobile Home/Trailer Parks	65%	NA
Medium_Den_Res	Medium-density Residential	27%	NA
Low_Den_Res	LDR, Vacant, Recreation, Urban Lawn	15%	1100 Low Intensity Residential
Cropland	Row Crops	0%	2000 Agriculture
Non_Irrigated_crop	Non-irrigated Cropland	0%	2000 Agriculture
Irrigated_Crop	Irrigated Cropland	0%	2000 Agriculture
Pasture	Pasture/Hay/Ranches	0%	2000 Agriculture 2700 Horse Ranches
Orchard_Vine	Orchards & Vineyards	0%	2000 Agriculture
Dairy_Livestock	Dairy/Livestock	0%	2400 Dairy/Intens. Livestock

San Jacinto LU	Includes	Percent Impervious	Corresponding San Diego Region Model Land Use
Forest	Deciduous forest, coniferous forest, mixed forest, grassland/herbaceous, deciduous shrubland, herbaceous wetland, wooded wetland	0%	4000 Open Space
Open	Open space, bare rock, quarries, strip mines, gravel pits, transitional	0%	1600 Military 1800 Open Recreation 4000 Open Space 7000 Transitional
Septics	Parcels with failing septic systems (artificial land use to add subsurface load)	0%	NA

The relevant nutrient parameters for Total N and Total P are shown by land use in Table 8 and Table 9. Note that the parameters are often the same across different land uses, which helps to resolve potential conflicts in the land use matching between the two models.

In sum, the San Jacinto model parameters provide a starting point for the San Diego lagoon watershed models. These parameters will likely need to be adjusted during Phase II of this project to achieve a satisfactory match to observation.

Table 8. San Jacinto Model Parameters for Total Nitrogen

Land Use	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Urban (pervious)	0.02136	0.5	1.64	0.237	0.237
High_Den_Res (pervious)	0.0801	0.5	1.64	0.008	0.008
Mobile_Trailor (pervious)	0.0801	0.5	1.64	0.031	0.031
Medium_Den_Res (pervious)	0.03916	0.5	1.64	0.028	0.028
Low_Den_Res (pervious)	0.02136	0.5	1.64	0.028	0.028
Cropland	0.2873	1-1.5*	1.64	3	3
Irrigated_Crop	0.34476	1.5	1.64	3	3
Non_Irrigated_crop	0.2873	1-1.5*	1.64	3	3
Pasture	0.14664	0.5	1.64	3	3
Orchard_Vine	0.00978	0.5	1.64	1	1
Dairy_Livestock	0.00978	0.5	1.64	89	89
Forest	0.00489	0.5	1.64	0.5	0.5
Open	0.01246	0.5	1.64	1.5	1.5
Urban (impervious)	0.09968	0.5	1.64	0	0
High_Den_Res (impervious)	0.1602	0.5	1.64	0	0
Mobile_Trailor (impervious)	0.1602	0.5	1.64	0	0
Medium_Den_Res (impervious)	0.1602	0.5	1.64	0	0

Land Use	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Low_Den_Res (impervious)	0.0801	0.5	1.64	0	0
Septics	0	0	0	133.33	0

* Higher values entered for Group 2, perhaps in error.

Table 9. San Jacinto Model Parameters for Total Phosphorus

Land Use	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
Urban (pervious)	0.001184	0.1	0.6	0.4	0.4
High_Den_Res (pervious)	0.004859	0.1	0.6	0.0073	0.0073
Mobile_Trailor (pervious)	0.004859	0.1	0.6	0.0073	0.0073
Medium_Den_Res (pervious)	0.00243	0.1	0.6	0.0023	0.0023
Low_Den_Res (pervious)	0.000997	0.1	0.6	0.0015	0.0015
Cropland	0.18	0.6	3	1.3	1.3
Irrigated_Crop	0.18	0.6	3	1.3	1.3
Non_Irrigated_crop	0.18	0.6	3	1.3	1.3
Pasture	0.00172	0.4	1.64	0.3	0.3
Orchard_Vine	0.00054	0.4	1.64	0.2	0.2
Dairy_Livestock	0.00054	0.4	1.64	8.9	8.9
Forest	0.00054	0.4	1.64	0.2	0.2
Open	0.00146	0.4	1.64	0.1	0.1
Urban (impervious)	0.004174	0.1	0.6	0	0
High_Den_Res (impervious)	0.006978	0.1	0.6	0	0
Mobile_Trailor (impervious)	0.006978	0.1	0.6	0	0
Medium_Den_Res (impervious)	0.006978	0.1	0.6	0	0
Low_Den_Res (impervious)	0.002804	0.1	0.6	0	0
Septics	0	0	0	10	0

2.5 CURRENT WATERSHED MODEL STATUS AND FILE NAMES

LSPC/HSPF models have been configured for seven lagoon watersheds, and initial testing was conducted. The models have been set up with initial parameter values derived from prior studies and other available data. Initial testing of hydrology focused on Santa Margarita and Agua Hedionda and suggests the need for continued refinement in Phase II. In addition, calibration of water quality parameters will be conducted in Phase II following the completion of the ongoing, intensive monitoring effort. A guide to file names is provided in Table 10.

Table 10. San Diego Region Lagoon Watershed Model Files

Watershed	Model Type	Primary Input File	Supporting File
Santa Margarita	WinHSPF	santamg09-newLU_C.uci	santam2.wdm smrmet.wdm
All Other Watersheds	LSPC	SDLagoons.inp	SanDiego_4-01-NewLanduse V3.mdb SDLagoons_PointSource.inp

3 Lagoon Models

In Phase I, EFDC models were set up for each of the listed lagoons. The status of these receiving water models is described below.

3.1 DEVELOPMENT OF EFDC MODEL GRIDS

The lagoons and estuaries are modeled using the EFDC model framework (Hamrick, 1992). Configuration of the EFDC models for the lagoons involved identifying and processing bathymetric data, developing model grids, defining boundary and initial conditions, and creating a linkage with the existing watershed model as model inputs.

The first step to configure the lagoon EFDC models is to determine the computational domain (i.e., define the EFDC model grid for the lagoon). Computation grids are the base for solving the governing equations of EFDC. The grid generation depends on the lagoon shorelines and the bathymetry of the lagoons. Grids were developed using the best available data. The bathymetry for Agua Hedionda Lagoon, Famosa Slough, and Loma Alta Lagoon are shown in Figure 18, Figure 19, and Figure 20 as contour lines. Bathymetric data for other lagoons are not available or the data coverage is not sufficient for calculating the depth. If additional bathymetric data become available in the future, the grids will be updated.

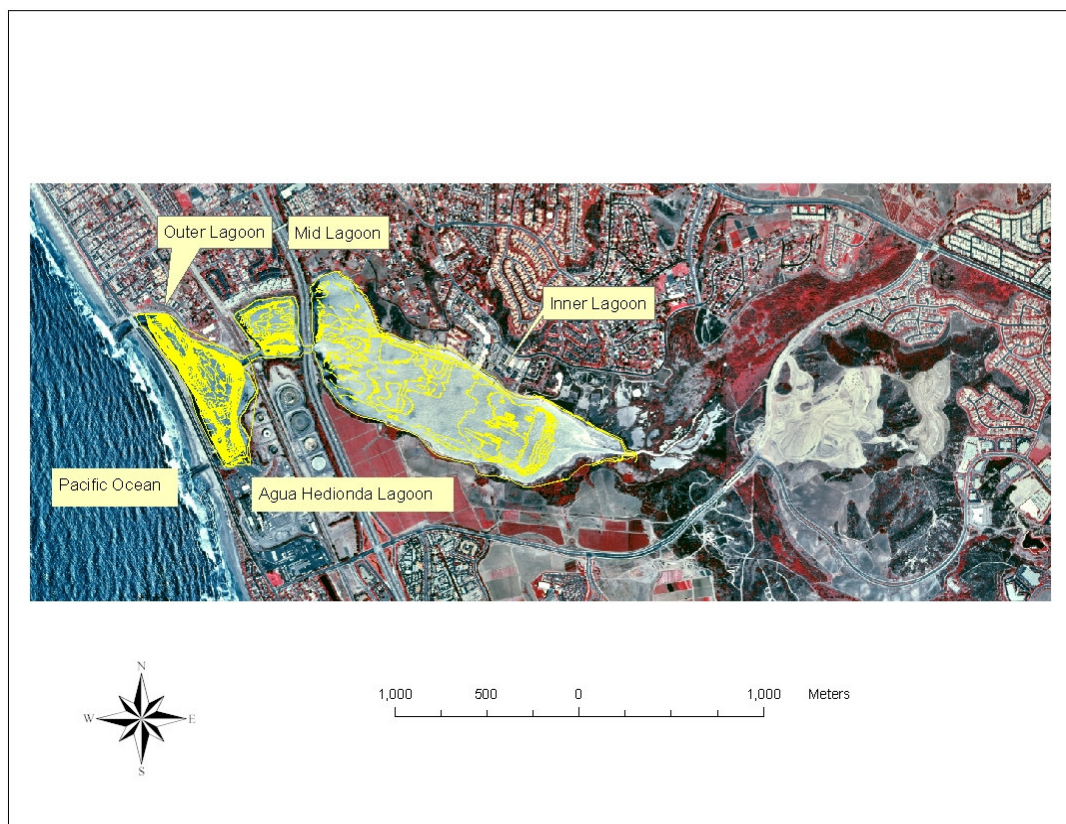


Figure 18. Bathymetry of Agua Hedionda Lagoon



Figure 19. Bathymetry of Famosa Slough



Figure 20. Bathymetry of Loma Alta Lagoon

3.1.1 Agua Hedionda Lagoon

The generated EFDC grid of Agua Hedionda Lagoon is shown in Figure 21. As can be seen in the figure, the grid follows the shoreline of the lagoon, and there are 395 computation cells. Contours of the bathymetry were used to calculate the average depth of each cell. This was done using the ArcGIS 3D Analyst and Spatial Analyst tools.

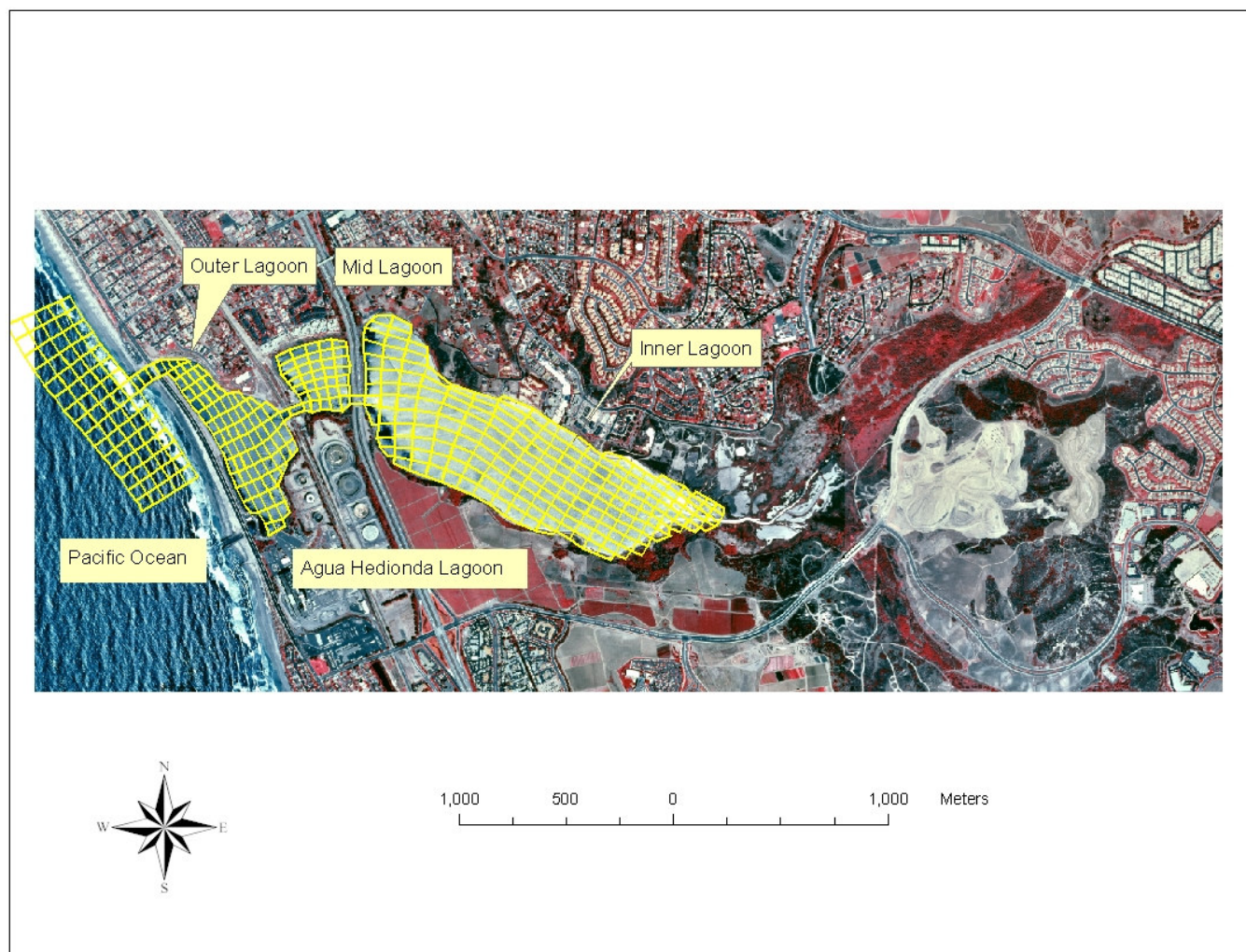


Figure 21. EFDC grid for Agua Hedionda Lagoon

3.1.2 Famosa Slough

The grid of Famosa Slough (Figure 22) is composed of three portions, the San Diego River, Famosa Channel, and Famosa Slough. The three sections are connected by hydraulic structures including flap valves, and culverts. These structures govern the flow direction. During low tide, the water can be flowing from the slough to the channel from box culverts (2–4 x 6 feet) and then to the San Diego River via culverts (from 3- to 60-inch RCP pipes). During high tide, the ocean water is mixed with some of the San Diego River water, and the water flows through flap valves into the Slough channel. Culvert pipes under West Point Loma Boulevard allow the water to flow into the Slough, to the channel, and then to the slough.

The culvert size and invert information is available. However, the valve information is not available, and the control table (rating curve between flow and depth within EFDC) cannot be established for all the hydraulic structures. Therefore, the current model is set as free-flowing without the structures. When the valve information is available, it will be processed into a control table, and the model will be updated to represent the actual controlled waterbody instead of as a free-flowing waterbody.

The grid was made to follow the shoreline and consists of 99 computation cells. Contours of the bathymetry were used to calculate the average depth of each cell using the ArcGIS 3D Analyst and Spatial Analyst tools.



Figure 22. EFDC Grid for Famosa Slough

3.1.3 Loma Alta Lagoon

The grid for Loma Alta Lagoon (Figure 23) is composed of two portions – the lagoon itself and the ocean. A sandy berm is between the ocean and the lagoon and controls the water flowing into or out of the lagoon. In the EFDC model, the sandy berm is configured as one cell that can change between wet and dry according to the water elevation and the elevation of the berm. The grid follows the shoreline of the lagoon, and there are 62 computation cells. Contours of the bathymetry were used to calculate the average depth of each cell using the ArcGIS 3D Analyst and Spatial Analyst tools.



Figure 23. EFDC Grid for Loma Alta Lagoon

3.1.4 Los Penasquitos Lagoon

The Los Penasquitos Lagoon is composed of both deep and shallow channels, and it connects with the ocean through a narrow ocean inlet. Grid generation is mainly based on the available satellite image. The EFDC grid for the lagoon includes two portions—the lagoon itself and the ocean. There are 204 computation cells. The channels near the ocean inlet are wider than the upstream channels and have finer resolution. The grid is shown in Figure 24.

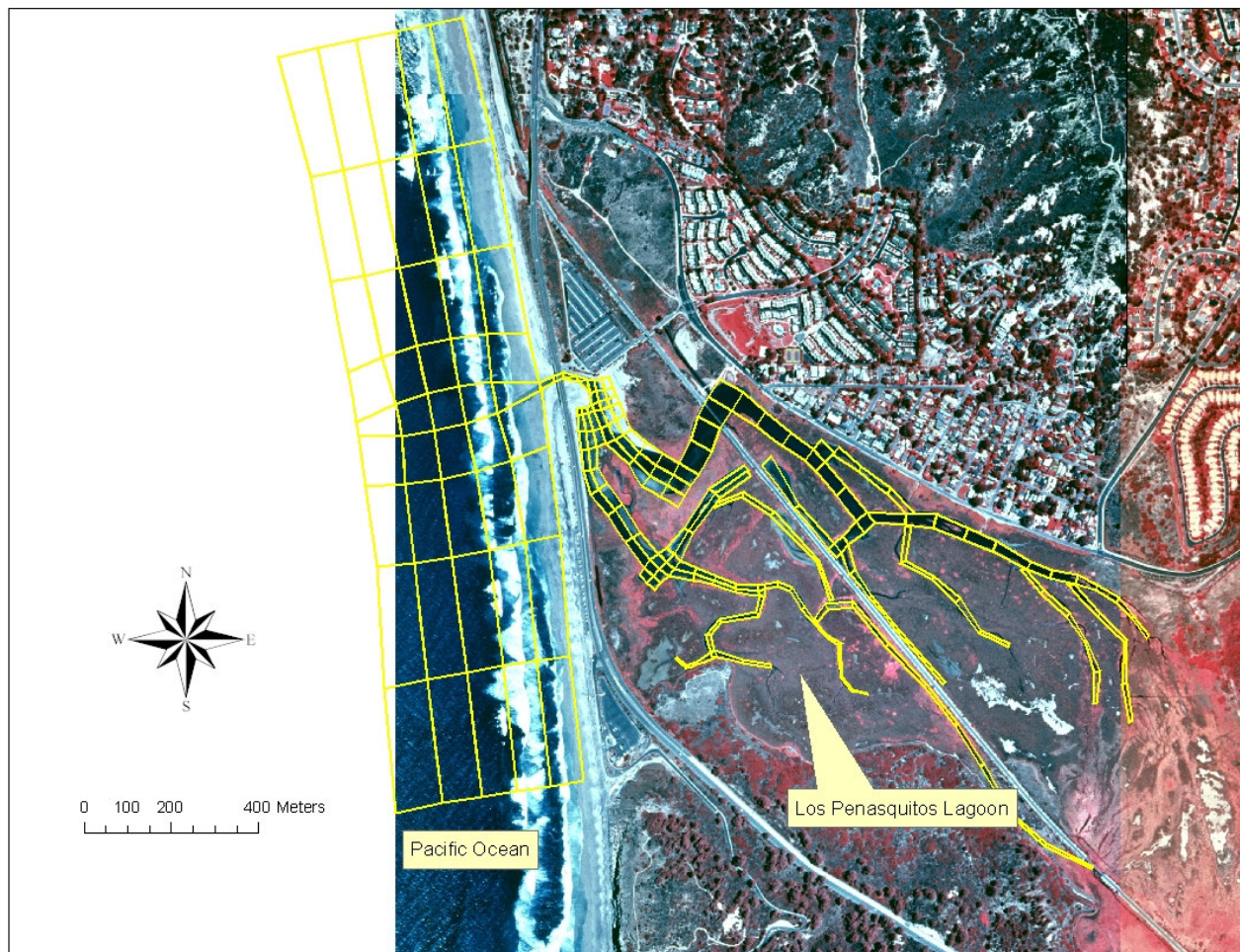


Figure 24. EFDC Grid for Los Penasquitos Lagoon

3.1.5 San Elijo Lagoon

The bathymetry of San Elijo Lagoon is not available. The grid was generated from one satellite image, which clearly shows a main channel and some pooled areas. It is unclear to what extent the water will cover under high tide conditions. The grid will be updated when the detailed bathymetry information is available. The current EFDC grid for San Elijo Lagoon is composed of the lagoon itself and the ocean boundary. There are 260 computation cells. The grid is shown in Figure 25.

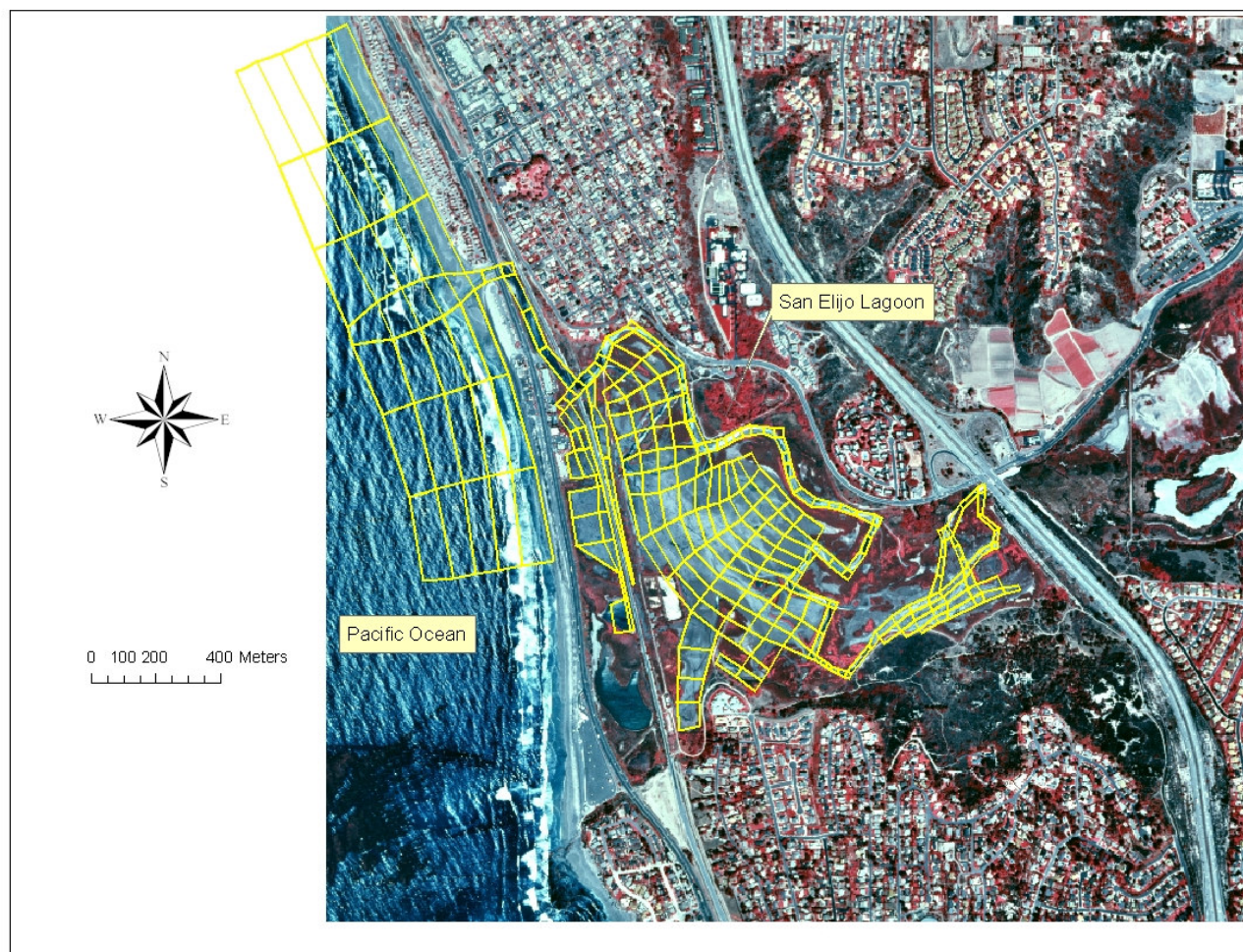


Figure 25. EFDC Grid for San Elijo Lagoon

3.1.6 Santa Margarita Estuary

The mouth of the Santa Margarita Estuary can change significantly. Historical pictures show that the mouth can be closed completely during certain periods. Even during periods when the estuary connects to the ocean freely, the ocean inlet location can be at different locations. The current grid was generated using the 2002 satellite image. The grid will be updated when new bathymetry information is available for the period when field sampling was conducted. The grid is composed of two portions including the ocean and the estuary. There are 226 computation cells for Santa Margarita Estuary EFDC model. The grid is shown in Figure 26.



Figure 26. EFDC Grid for Santa Margarita Estuary

3.2 METEOROLOGICAL DATA

Meteorological data are an important component of the EFDC model. The surface boundary conditions are determined by the meteorological conditions. The meteorological data required by the EFDC model are atmospheric pressure, air temperature, relative humidity, precipitation, cloud cover, solar radiation, wind speed, and wind direction.

Hourly surface airways meteorological data from several locations in the vicinity of the lagoons were downloaded from the National Climatic Data Center (NCDC). The data were converted to the appropriate units and formatted to the EFDC input format. The locations of these stations are shown in Figure 27.

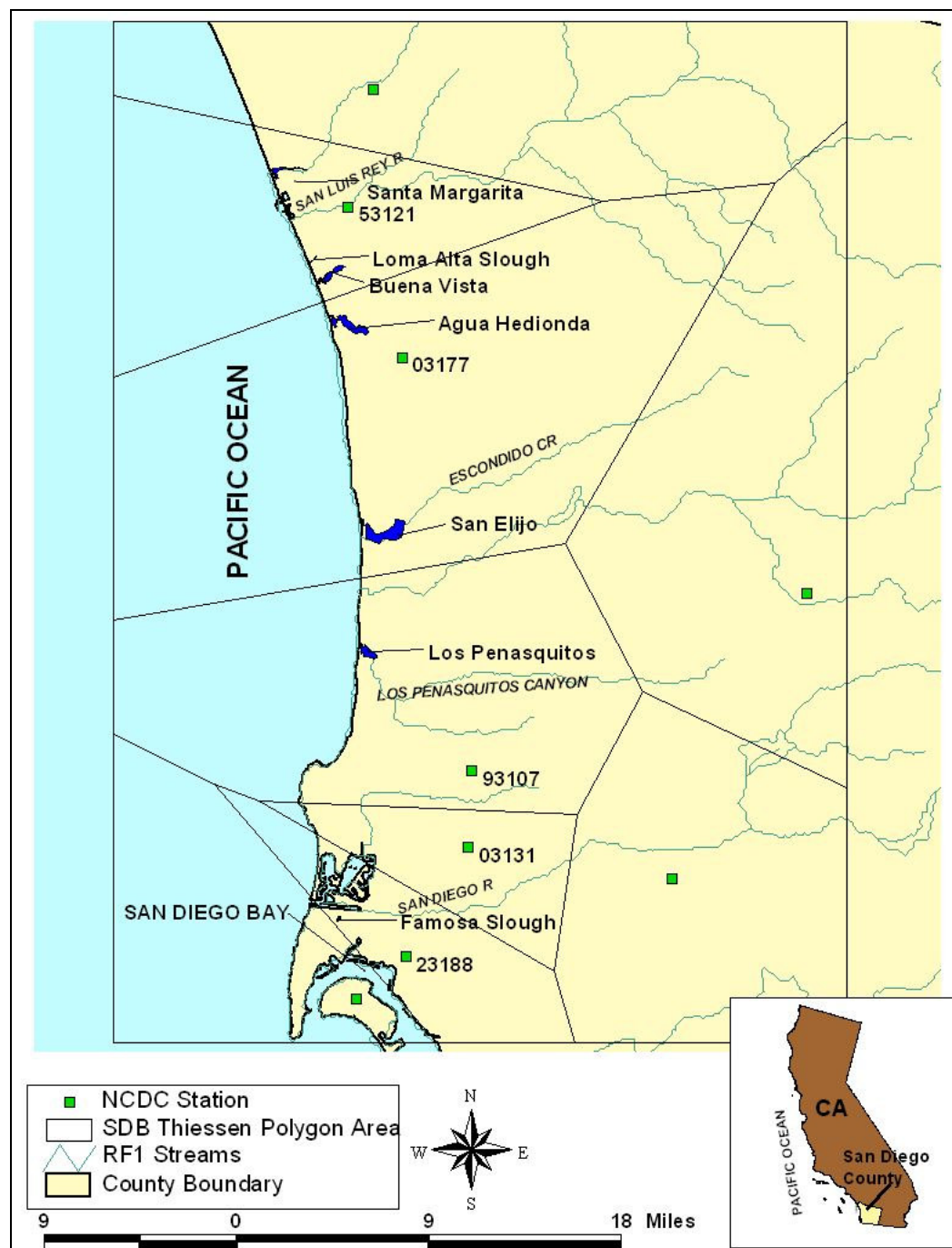


Figure 27. Weather Stations for Lagoon Models

These surface airways stations were chosen because they were the closest in terms of proximity and had the most complete coverage of data. A Thiessen polygon was also created to aid in assignment of the NCDC station to appropriate lagoons because the weather stations are scattered. Table 11 below shows a list of meteorological stations that will ultimately be assigned during calibration and validation.

Table 11. Meteorological Station Assignment

Station ID	Description	Lagoon	Start date	End date	Percent complete
53121	Oceanside Municipal Airport, Oceanside	Santa Margarita/Loma Alta	5/11/1999	3/30/2008	100%
03177	McClellan–Palomar Airport, Carlsbad	Agua Hedionda/San Elijo	2/19/1998	3/30/2008	100%
93107	Marine Corps Air Station, Miramar	Los Pensaquitos	11/1/1999	3/30/2008	100%
03131	Montgomery Field Airport, San Diego	Famosa Slough	2/19/1998	3/30/2008	100%
23188	San Diego International Airport, San Diego	Famosa Slough	7/1/1996	3/30/2008	100%
Famosa_MES	Famosa Mass Emission Site	Famosa Slough	10/1/2007	1/31/2008	98%

Observed hourly meteorological data were also available from the Famosa Mass Emission Site (Famosa_MES). This station did not have any solar radiation or cloud cover measurements and had some missing days in the month of November 2007 (18 days). Data from station 23188 were used to patch the missing data in the Famosa_MES site. All the data were processed and formatted to EFDC meteorological data file format.

For initial model testing, all the lagoon models use the data from station 23188.

3.3 WATERSHED BOUNDARY CONDITIONS

The watershed is the main source of sediment and nutrients for the lagoons. LSPC/HSPF models were developed for the drainage areas of the lagoons. Flow and pollutant loadings were simulated from the LSPC models. The calibrated model results will be used to provide wet-weather flows and concentrations to the EFDC model. The dry-weather loads to EFDC will be represented on the basis of gaged flows and observed water quality. For the streams entering the lagoons without USGS gages, LSPC results were used for the lagoon model test. Table 12 shows the LSPC reach ID assignment to the corresponding lagoon. Note that for Santa Margarita, the watershed input was based on USGS gage data from the Santa Margarita River at Ysidora. The details of the watershed model development and reach ID numbers are in Section 2.

Table 12. Watershed Loading Linkages to Lagoon Models for Initial Testing

Reach ID	Waterbody	Remarks
800	Loma Alta Lagoon	LSPC model output
1201	San Elijo Lagoon	LSPC model output
1402	Los Penasquitos Lagoon	LSPC model output
2100	Agua Hedionda Lagoon	LSPC model output
2200	Famosa Slough	LSPC model output
	Santa Margarita Estuary	Based on USGS gage 11046000-SANTA MARGARITA R-Ysidora

The modeled flow are converted to the EFDC format directly by changing time to the Julian day format. LSPC usually models TN and TP, while EFDC requires more detailed species of N and P. Ratios of the N and P species will be estimated when more water quality data become available. For initial testing, TN and TP are evenly distributed to dissolved organic nitrogen (DON), particulate organic nitrogen (PON), ammonia, nitrate, and dissolved organic phosphorus (DOP), particulate organic phosphorus (POP), and orthophosphate (PO₄) for testing the water quality simulation. For fecal bacteria, the concentrations of fecal bacteria were converted to total load. For suspended sediment, a constant 100 mg/L of total suspended sediment (TSS) was used for model testing. A linkage Excel VBA tool has been developed for the lagoons to convert the LSPC results to EFDC input files automatically.

3.4 OCEAN BOUNDARY CONDITION

In addition to the watershed, the ocean has both hydrodynamics and water quality influences on the lagoons. The change of ocean water surface elevations determines the direction of flow and the water quality constituents. In addition, ocean water increases or decreases the concentrations of the pollutants in the lagoons depending on the ocean water quality.

Historic and current tide data locations were downloaded from the NOAA tides Web site. Out of a total of 16 stations, only 3 had tidal elevation data up to 2007 (Table 13). Figure 28 shows the three stations near the lagoons. Table 14 lists the data coverage.

Table 13. Tide Stations Near the Lagoons

Station name	Station ID	Start Date	End Date	Remarks
Los Angeles, CA	9410660	11/28/1923	12/31/2007	Verified Hourly & Monthly Mean Water Level
La Jolla, Pacific Ocean, CA	9410230	8/1/1924	12/31/2007	Verified Hourly & Monthly Mean Water Level
San Diego, CA	9410170	1/21/1906	12/31/2007	Verified Hourly & Monthly Mean Water Level

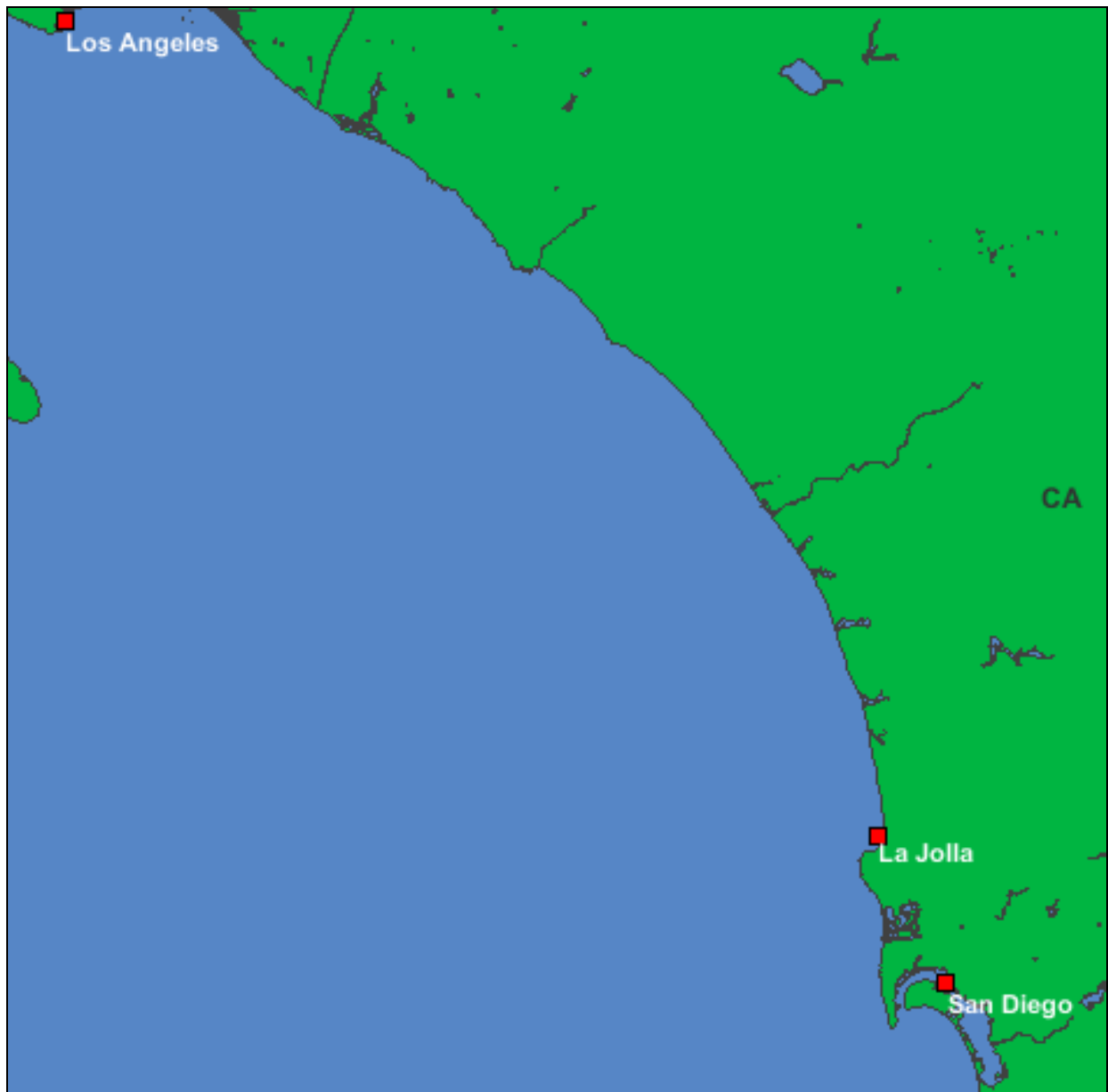


Figure 28. Tide Stations Near the Lagoons (Source: NOAA Web site)

Table 14. Tide Harmonic Constituents at the Three Stations

Harmonic Constituents\Stations	La Jolla, CA	San Diego, CA	Los Angeles, CA
M2 Amplitude (m)	0.500	0.556	0.515
M2 Phase	141.7	143.2	145.5
S2 Amplitude (m)	0.204	0.229	0.203
S2 Phase	136.7	140.2	141.1

Harmonic Constituents\Stations	La Jolla, CA	San Diego, CA	Los Angeles, CA
N2 Amplitude (m)	0.118	0.130	0.121
N2 Phase	120.1	123.8	123.7
K1 Amplitude (m)	0.336	0.347	0.343
K1 Phase	206.7	208	207.7
O1 Amplitude (m)	0.215	0.220	0.218
O1 Phase	191.2	192.4	192.3

Source: NOAA Web site: <http://tidesandcurrents.noaa.gov>

The tide data as Mean Lower Low Water (MLLW) from the four stations are plotted together to examine the spatial variations of the tidal elevations in the region as shown in Figure 29.

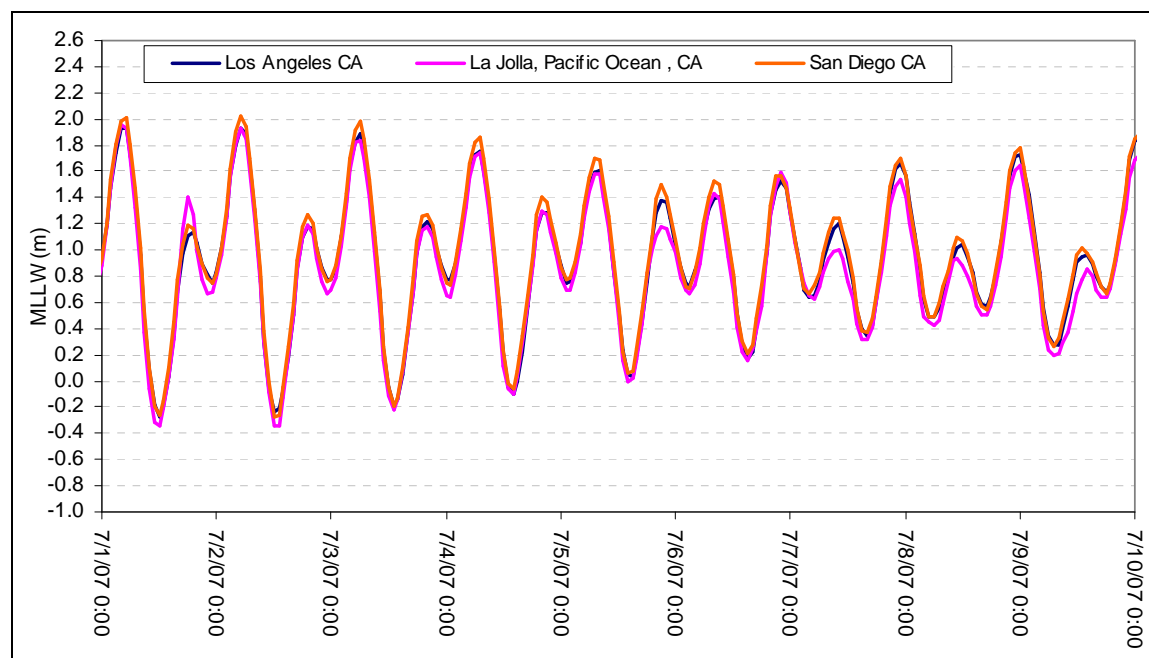


Figure 29. Tide Data Comparison from NOAA

Figure 29 illustrates that the differences of the amplitudes and phases among these stations are minimal, with the data for the San Diego Station being slightly higher than the other stations. Table 14 lists the five major tide harmonic constituents at the three stations. The ocean water surfaces at these stations reach approximately the same elevation at similar times. The tide data at La Jolla was used as open ocean water surface elevation boundaries for testing the lagoon models. The tide data from La Jolla was used because it was similar to other available tide data and provided a complete data set in terms of the time period available. If more site-specific tide data become available for certain lagoons, it can be easily incorporated into the model during calibration and validation.

The water quality information in the open ocean is not currently available. Because the purpose of Phase I is to set up and to test the models instead of calibrating the models, it is assumed that the ocean is at clean level for nutrients and all the nutrients are set as 0 in the lagoon models. For suspended sediment, the concentration in the open ocean is set to 10 mg/L. During the calibration period, the actual ocean water quality information is required, and the models will be updated to represent the actual conditions, which will depend on the monitoring results.

3.5 INITIAL TESTING RESULTS

After configuring the EFDC models for each lagoon, the models were tested mainly to examine the response of the models to the external driving forces. The watershed inflow is shown to examine the lagoon model response to inflow boundary conditions. The modeled hydrodynamic and water quality results are shown in the figures for each lagoon and the model results are discussed briefly. The purpose of presenting the model results is to show the correct response of the model to the external forces including tide and watershed inflow. The model results should not be considered a simulation of the actual lagoon water quality.

3.5.1 Agua Hedionda Lagoon

The Agua Hedionda Lagoon EFDC model was tested using tide data, weather data, and watershed LSPC results. The model was run for 30 days. Figure 30 shows the watershed inflow. The modeled water surface elevation, water temperature, salinity, suspended sediment are shown in Figure 31 through Figure 34.

The Agua Hedionda Lagoon EFDC model responds to the boundary conditions correctly. The water surface elevation changes in the lagoon corresponding to the tide elevation. The salinity was set to 0 initially for the entire lagoon. When the model was run, the salinity increased to around 35 ppt, which is the ocean salinity used as the boundary condition. Water temperature changes are due to solar radiation and air temperature. The modeled suspended sediments are high before day 5 and decrease afterwards corresponding to the watershed inflow.

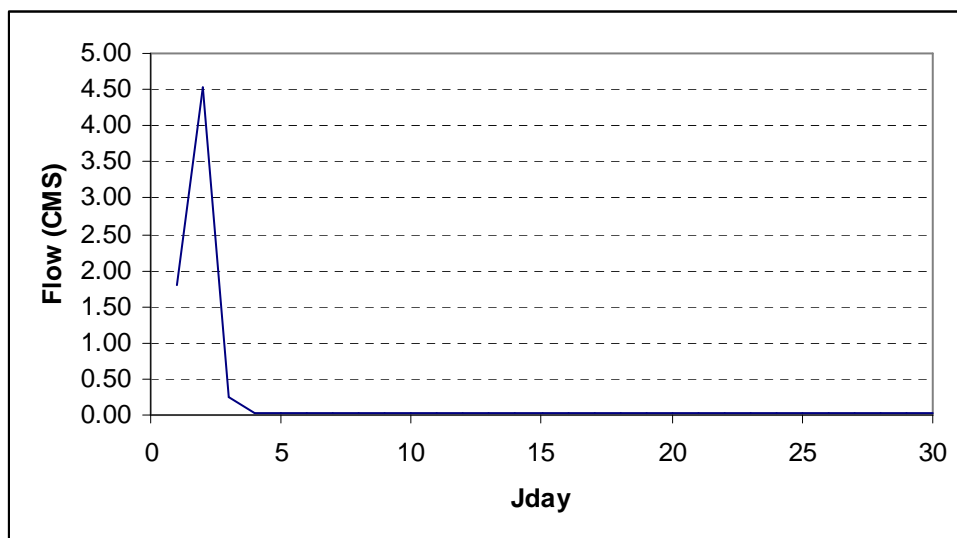


Figure 30. Watershed Inflow to Agua Hedionda Lagoon

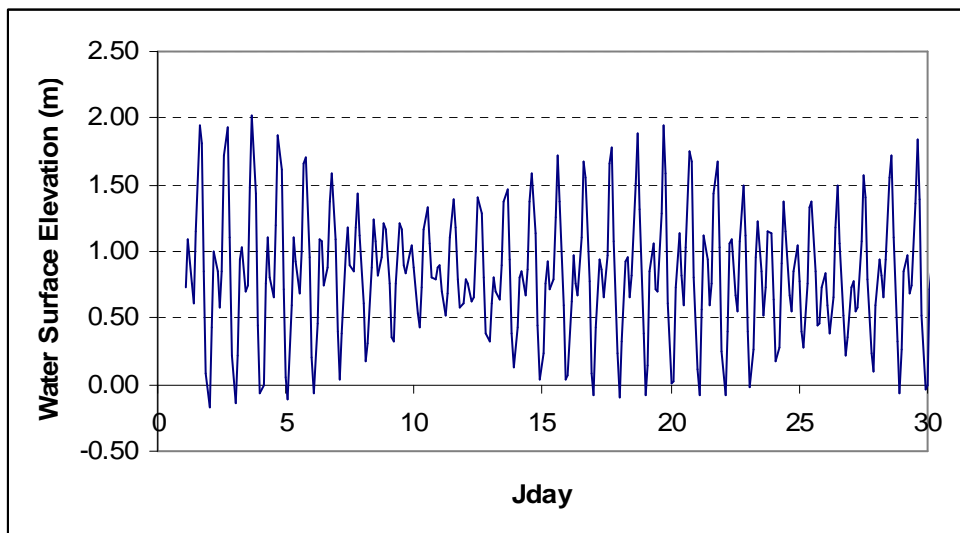


Figure 31. Modeled Water Surface Elevation in Agua Hedionda Lagoon

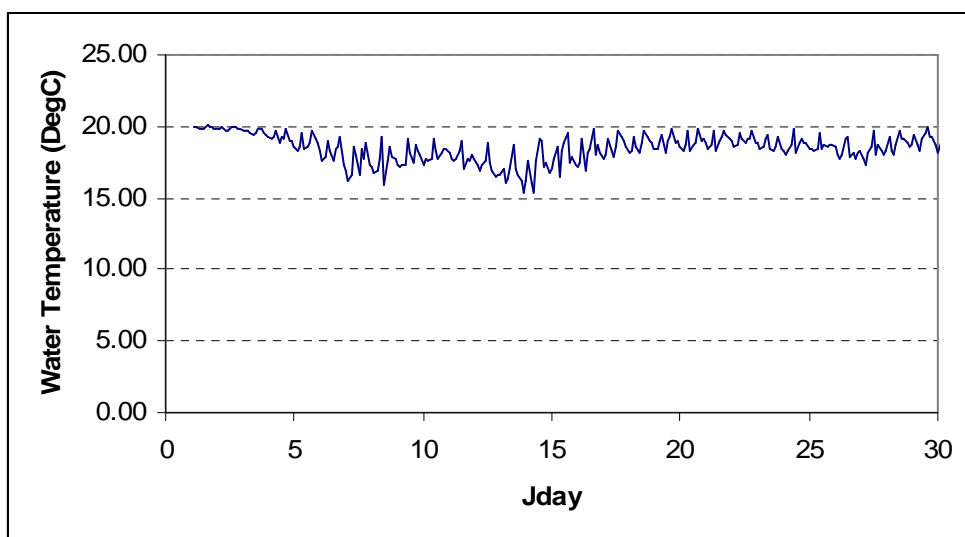


Figure 32. Modeled Water Temperature in Agua Hedionda Lagoon

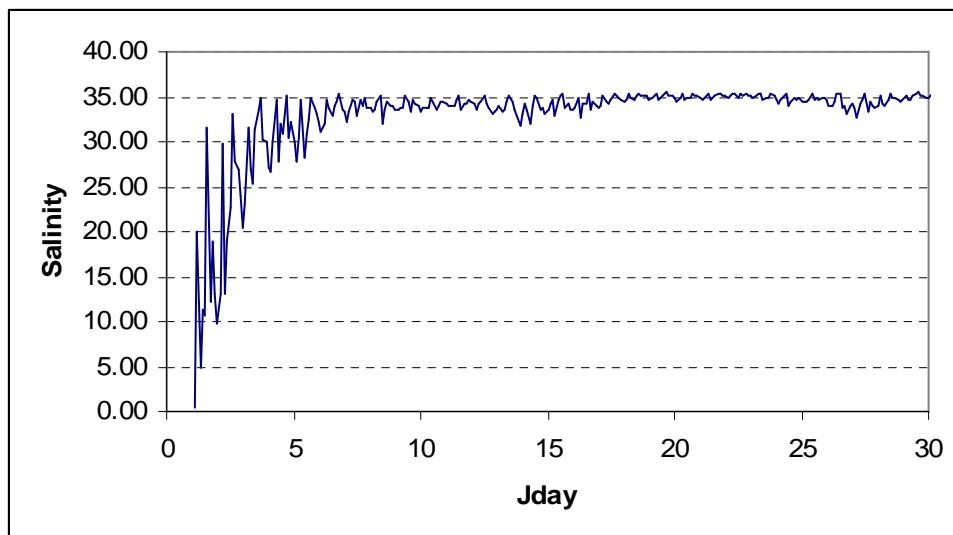


Figure 33. Modeled Salinity in Agua Hedionda Lagoon

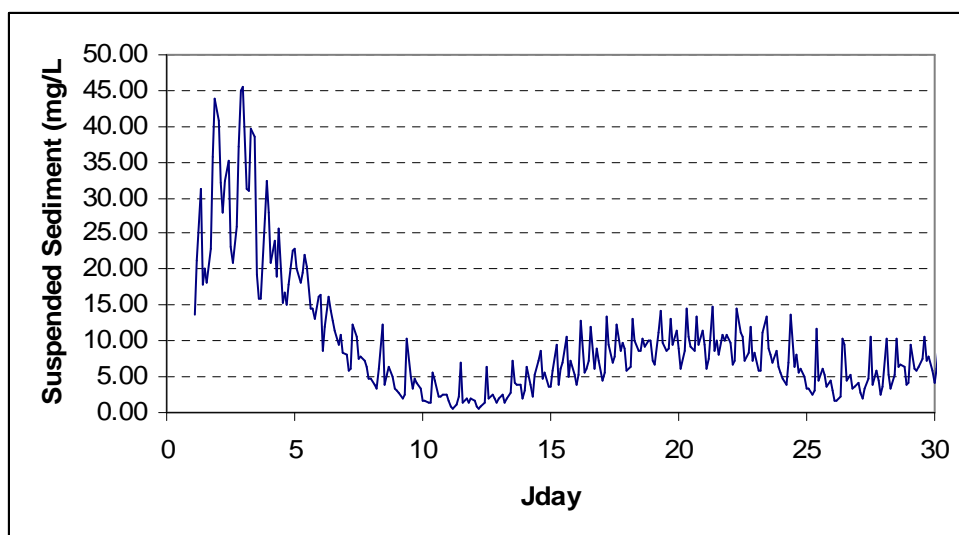


Figure 34. Modeled Suspended Sediment in Agua Hedionda

3.5.2 Famosa Slough

The Famosa Slough EFDC model was tested using tide data, weather data, and watershed LSPC results. The model was run for 30 days. The watershed inflow is shown in Figure 35. The modeled water surface elevation, water temperature, salinity, and DO are shown in Figure 36 through Figure 39.

Because Famosa Slough is configured as a free-flowing waterbody, the modeled water surface elevation follows the tidal elevation. The modeled water temperature changes under the effects of ocean and freshwater inflow temperature and meteorological conditions. The freshwater inflow to Famosa Slough is relatively low. The modeled salinity rapidly increases from 0 to 35. The modeled DO initially decreases due to the watershed loadings of ammonia and organic carbon and then increases near the saturation levels during dry days.

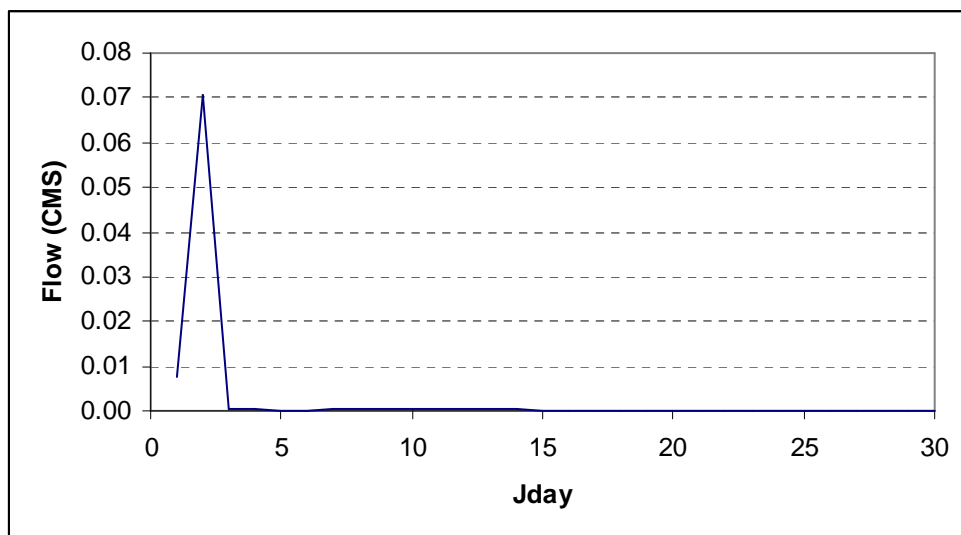


Figure 35. Watershed Inflow to Famosa Slough

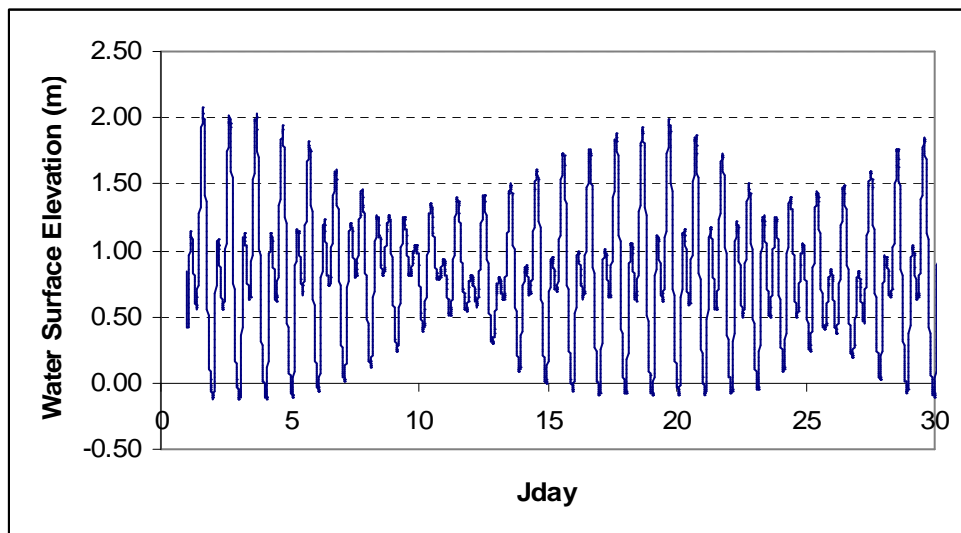


Figure 36. Modeled Water Surface Elevation in Famosa Slough

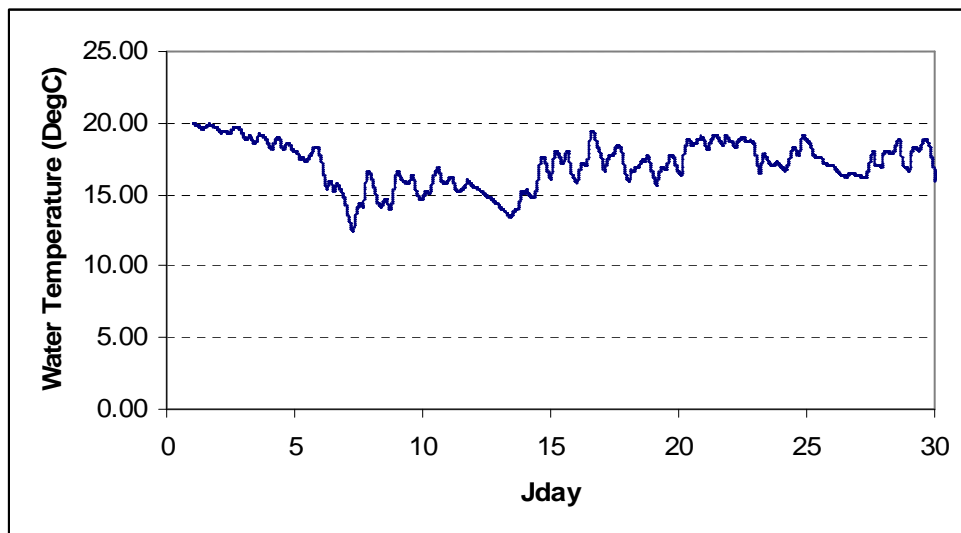


Figure 37. Modeled Water Temperature in Famosa Slough

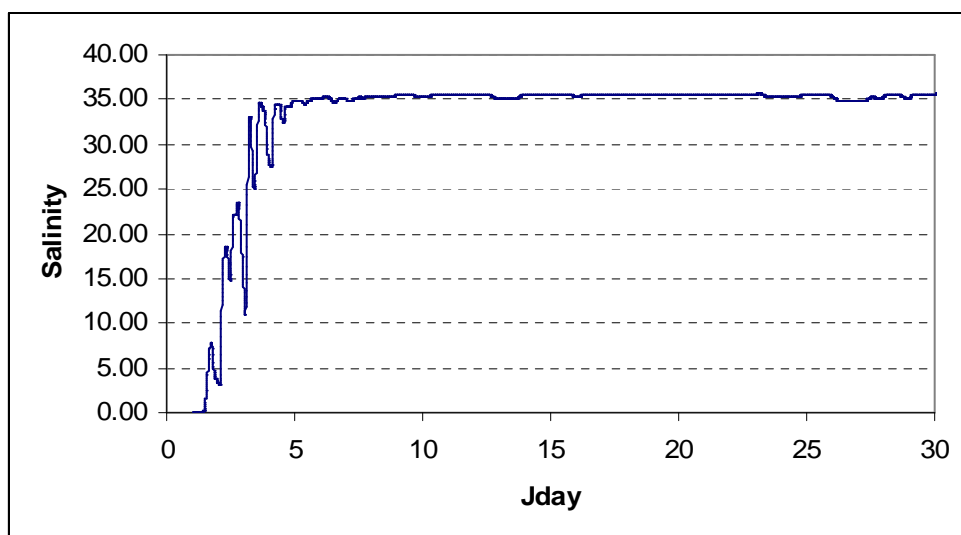


Figure 38. Modeled Salinity in Famosa Slough

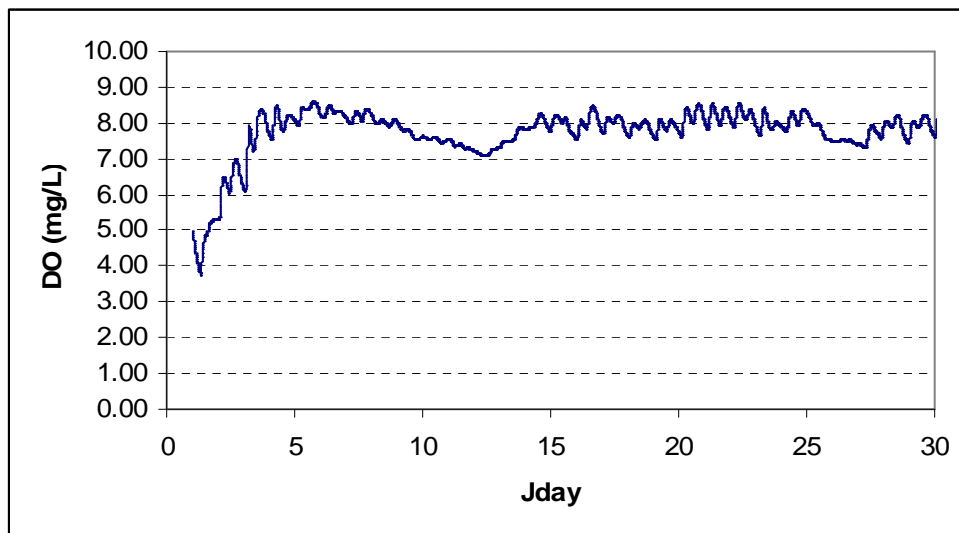


Figure 39. Modeled DO in Famosa Slough

3.5.3 Loma Alta Lagoon

The Loma Alta EFDC model was tested using tide data, weather data, and watershed LSPC results. The watershed inflow is shown in Figure 40. The model was run for 30 days. The modeled water surface elevation, water temperature, salinity, and DO are shown in Figure 41 through Figure 44.

The model results show that the model behavior responds to the bathymetry and boundary conditions correctly. The sandy berm controls whether there is flow between the lagoon and ocean. Unlike the lagoons with free connection to the ocean, the water surface elevation in Loma Alta Lagoon does not follow the tidal elevation, instead it is strongly affected by the watershed inflows. The salinity increases slowly and is diluted by freshwater quickly. The modeled DO decreases initially due to the high watershed loadings of ammonia and organic carbon. DO then increases gradually to near the saturation level.

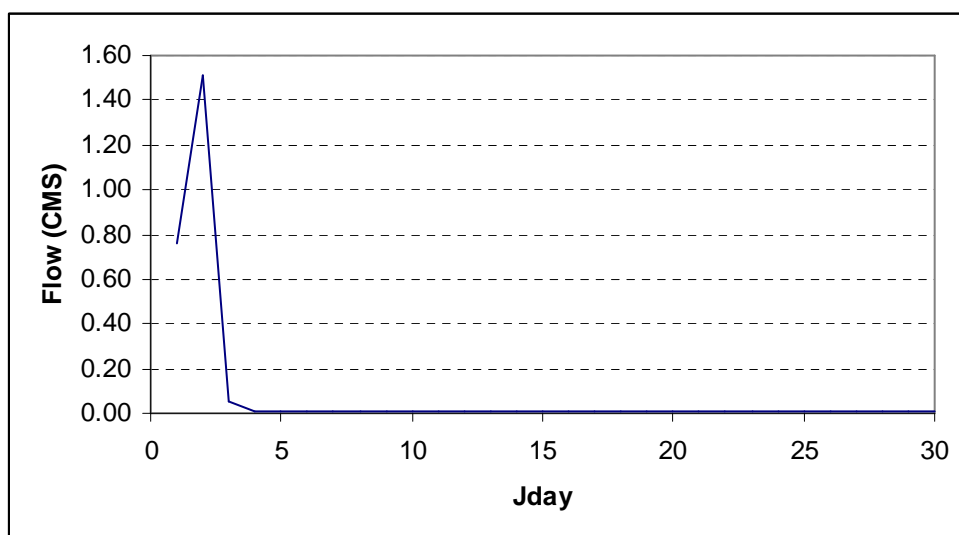


Figure 40. Watershed Inflow to Loma Alta Lagoon

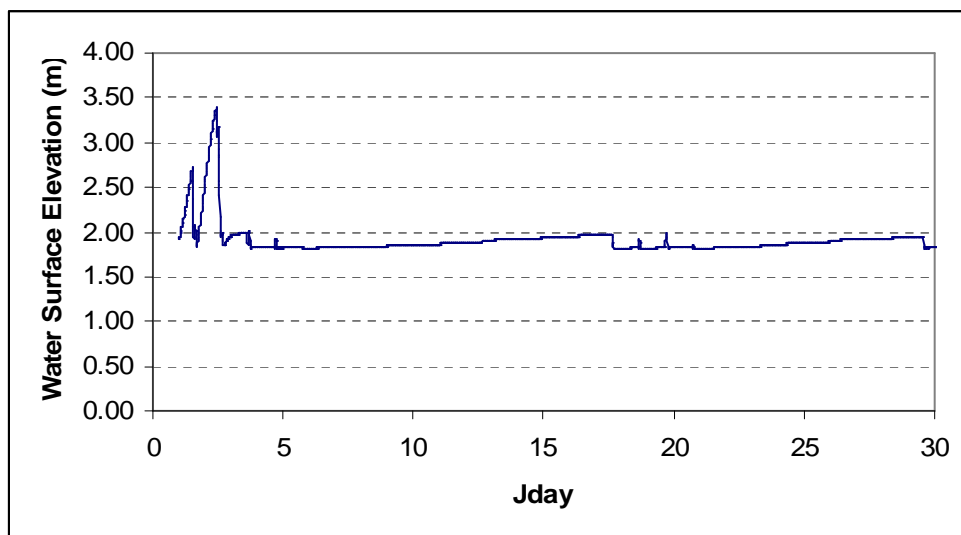


Figure 41. Modeled Water Surface Elevation in Loma Alta Lagoon

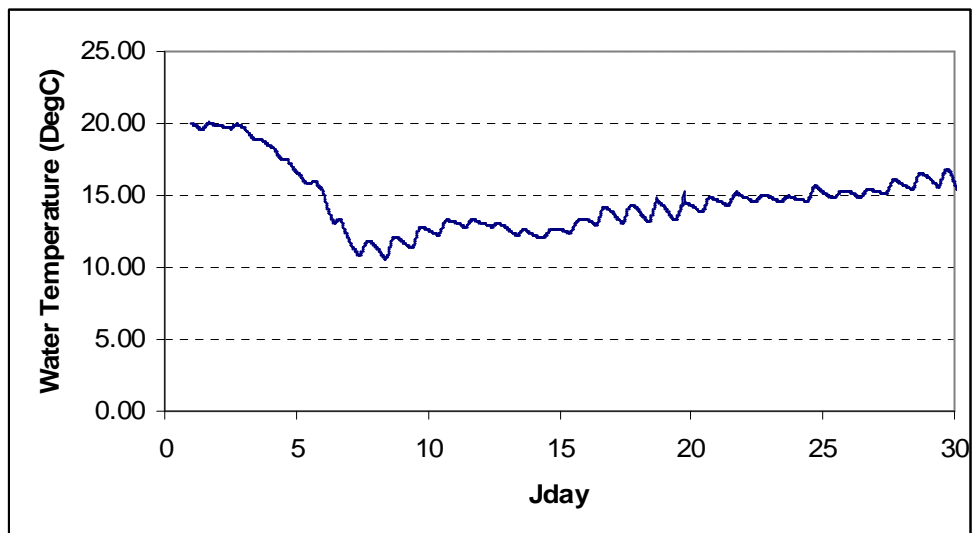


Figure 42. Modeled Water Temperature in Loma Alta Lagoon

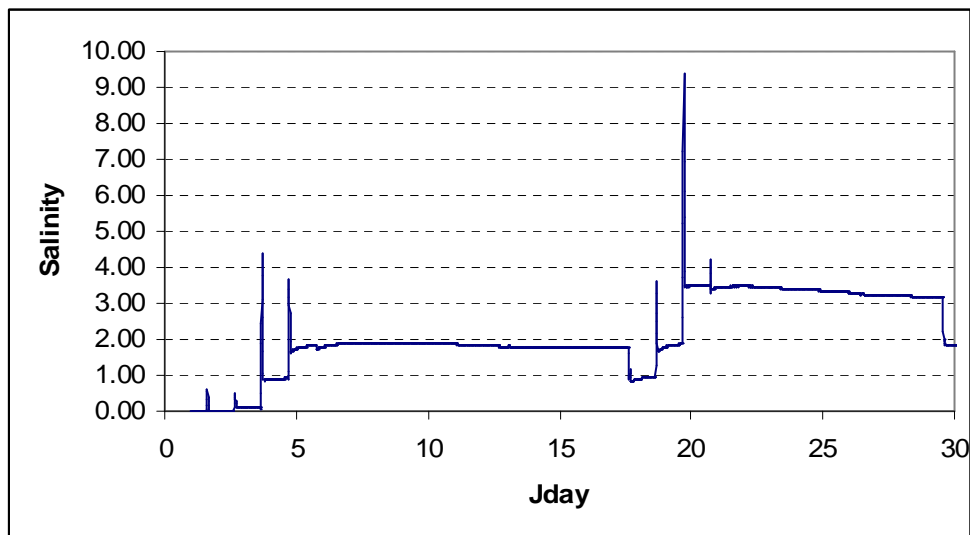


Figure 43. Modeled Salinity in Loma Alta Lagoon

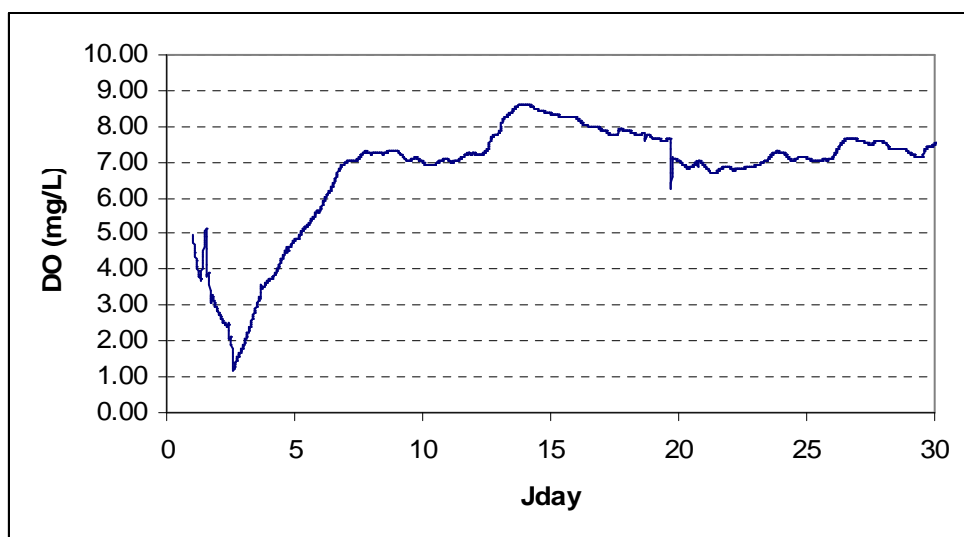


Figure 44. Modeled DO in Loma Alta Lagoon

3.5.4 Los Penasquitos Lagoon

The Los Penasquitos EFDC model was tested using tide data, weather data, and watershed LSPC results. The watershed inflow is shown in Figure 45. The model was run for 30 days. The modeled water surface elevation, water temperature, salinity, and suspended sediment are shown in Figure 46 through Figure 49.

The modeled water surface elevation follows the tidal elevation because the lagoon connects to the ocean freely. The modeled salinity shows strong effect by both the ocean and watershed freshwater inflow. The salinity changes dramatically according to the flood and ebb of tide along with watershed inflow. The modeled water temperature is more affected by the ocean and watershed inflow water temperature than the meteorological conditions. The modeled suspended sediment also shows the periodic influences by the tide and watershed inflow. When watershed inflow is high in the beginning of the simulation, erosion

occurs, and the modeled suspended sediment concentration exceeds 100 mg/L. During baseflow periods, the sediment concentration changes from near 100 mg/L to lower values during high tide.

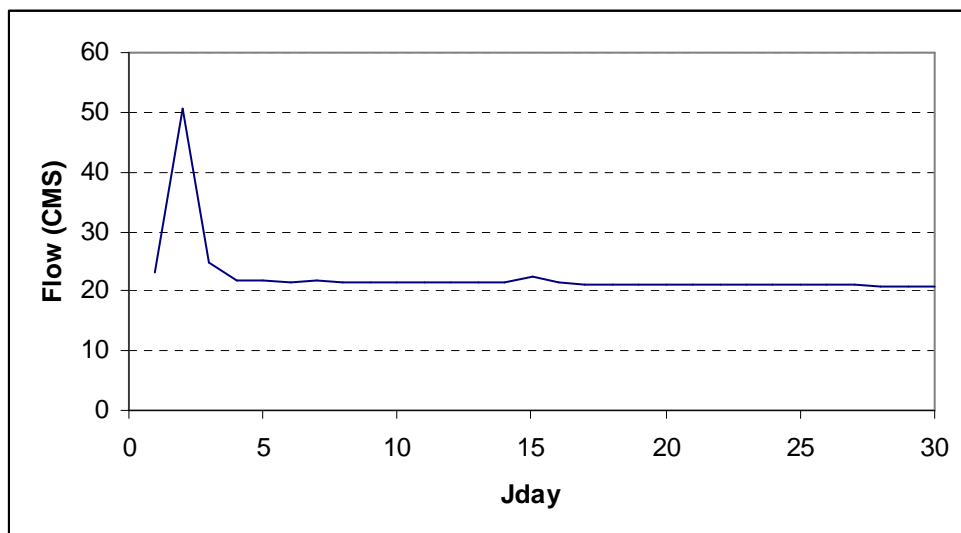


Figure 45. Watershed Inflow to Los Penasquitos Lagoon

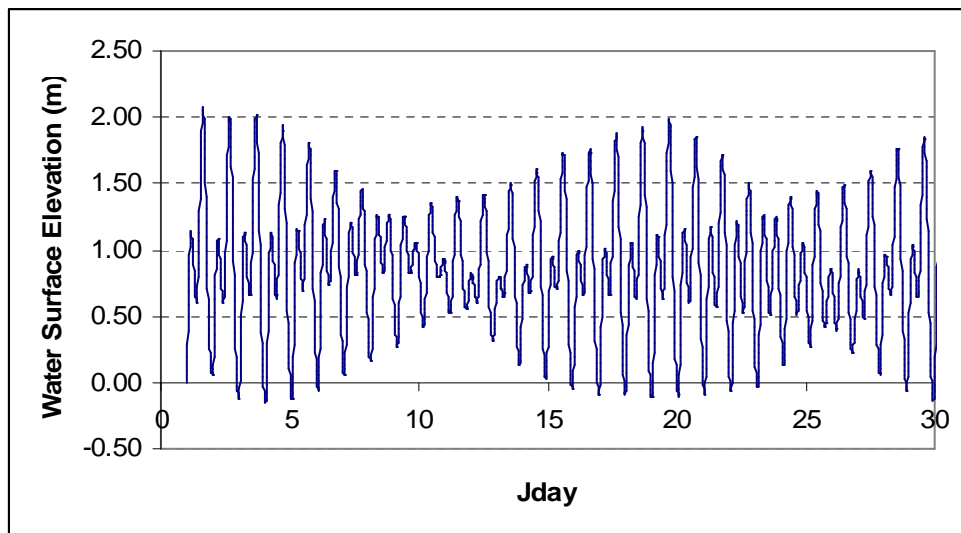


Figure 46. Modeled Water Surface Elevation in Los Penasquitos Lagoon

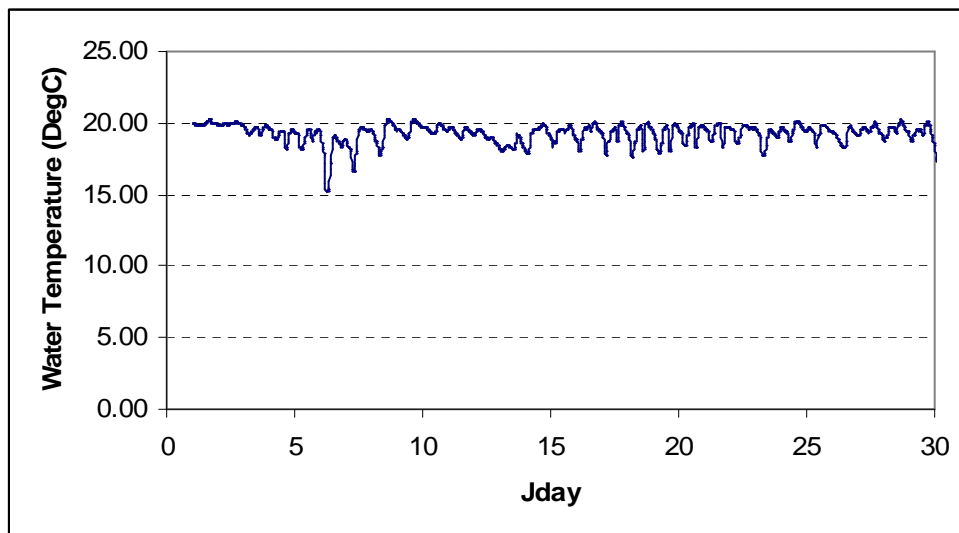


Figure 47. Modeled Water Temperature in Los Penasquitos Lagoon

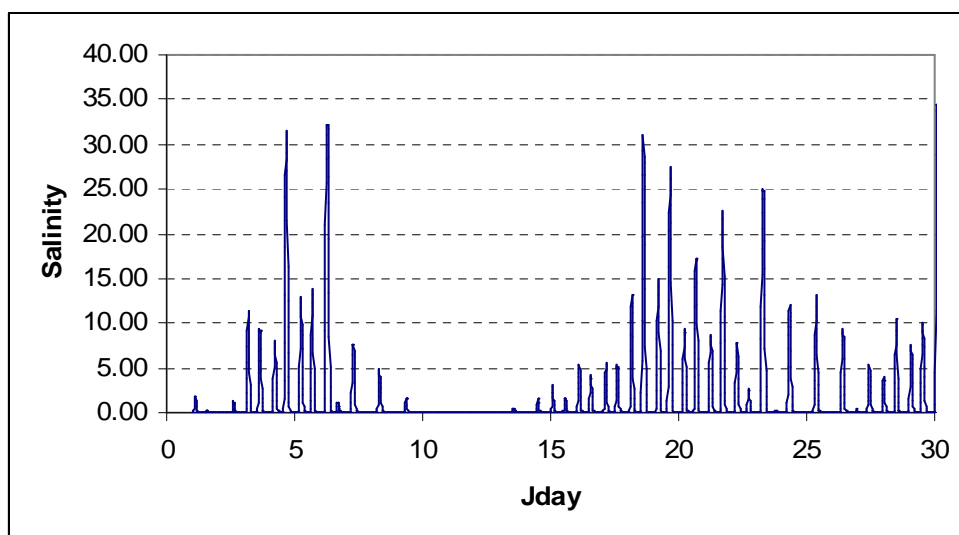


Figure 48. Modeled Salinity in Los Penasquitos Lagoon

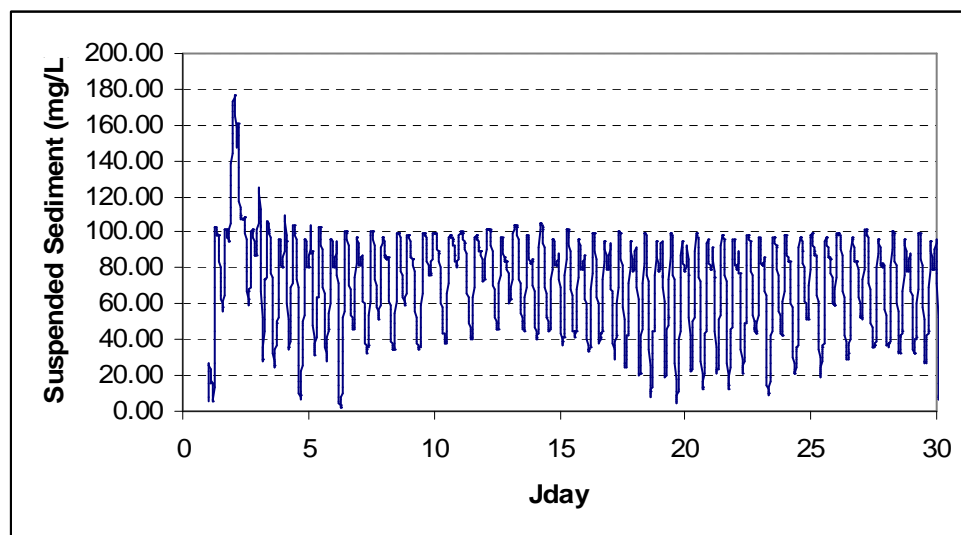


Figure 49. Modeled Suspended Sediment in Los Penasquitos Lagoon

3.5.5 San Elijo Lagoon

The San Elijo EFDC model was tested using tide data, weather data, and watershed LSPC results. The watershed inflow is shown in Figure 50. The model was run for 30 days. The modeled water surface elevation, water temperature, salinity, suspended sediment, and DO are shown in Figure 51 through Figure 55.

The modeled water surface elevation follows the tidal elevation similar to Los Penasquitos Lagoon because San Elijo Lagoon also connects to the ocean freely. The modeled salinity shows that the influences of the ocean and the watershed inflow are both significant. The salinity changes dramatically from around 0 to 35 according to tide and watershed inflow. The modeled water temperature is more affected by the ocean and watershed inflow water temperature than by the meteorological conditions. The modeled suspended sediment also shows the periodic influences by the tide and watershed inflow. Compared to Los Penasquitos Lagoon, the lagoon area of San Elijo is much larger, and the ocean water effect is stronger than the watershed inflow for the modeling period. The suspended sediment concentration is set to 100 mg/L in the watershed inflow and 10 mg/L in the ocean. The modeled suspended sediment concentration never exceeds 100 mg/L because of the higher volume of ocean water than watershed inflow at the model output location. During the baseflow period, the sediment concentration decreases to around 10 mg/L, which is the assigned ocean suspended sediment concentration. The modeled DO is lower than the saturation level due to the high ammonia input from the watershed and the ocean.

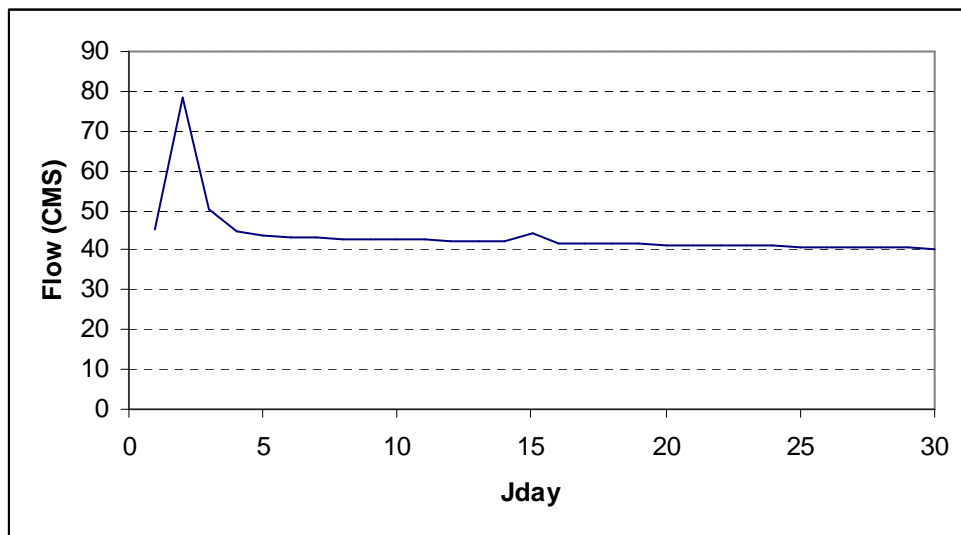


Figure 50. Watershed Inflow to San Elijo Lagoon

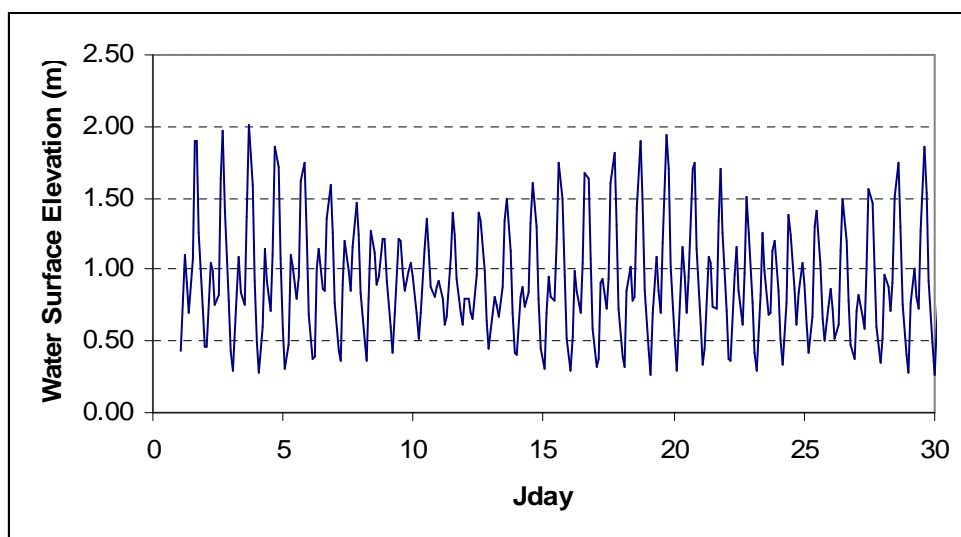


Figure 51. Modeled Water Surface Elevation in San Elijo Lagoon

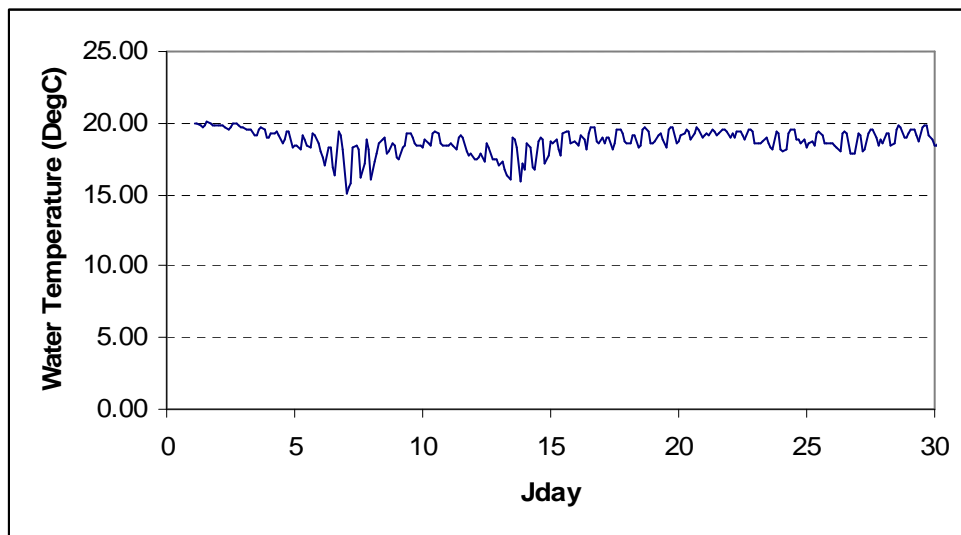


Figure 52. Modeled Water Temperature in San Elijo Lagoon

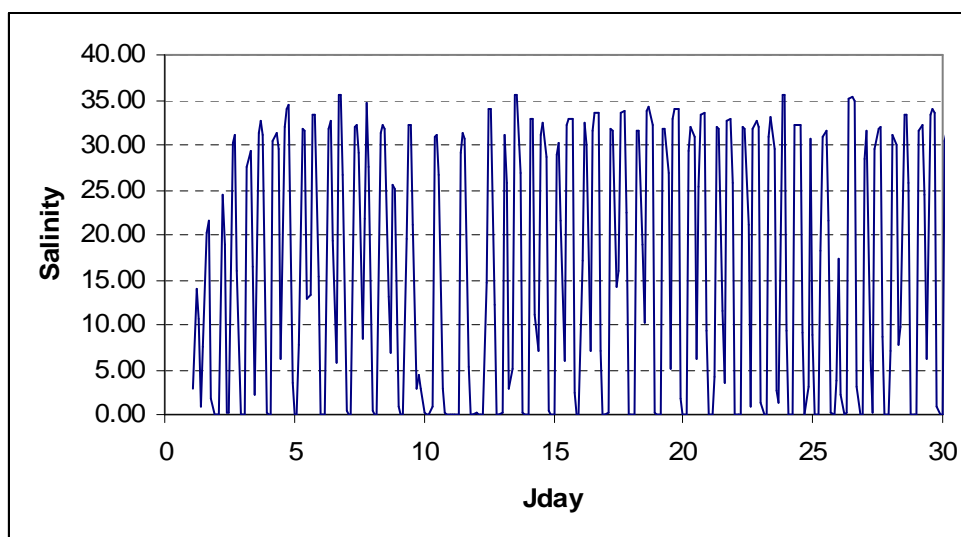


Figure 53. Modeled Salinity in San Elijo Lagoon

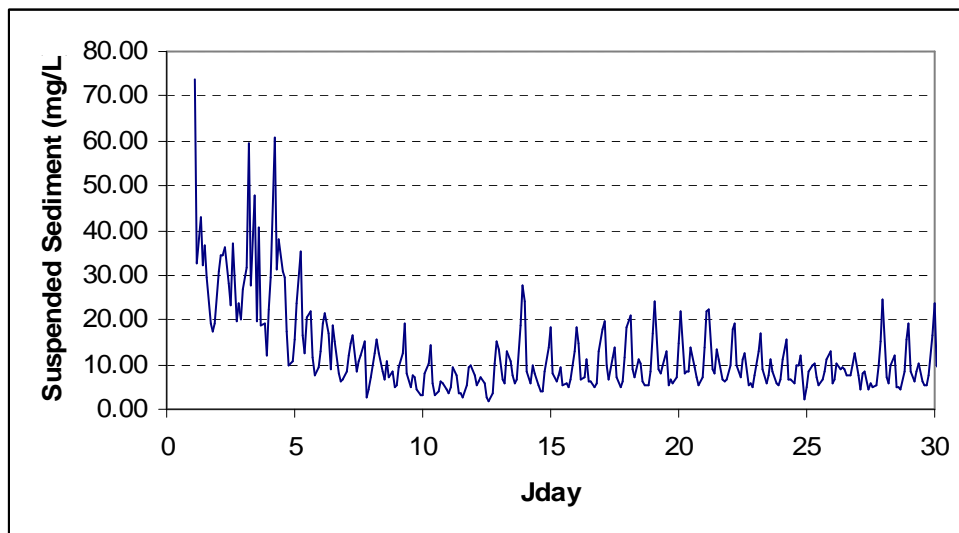


Figure 54. Modeled Suspended Sediment in San Elijo Lagoon

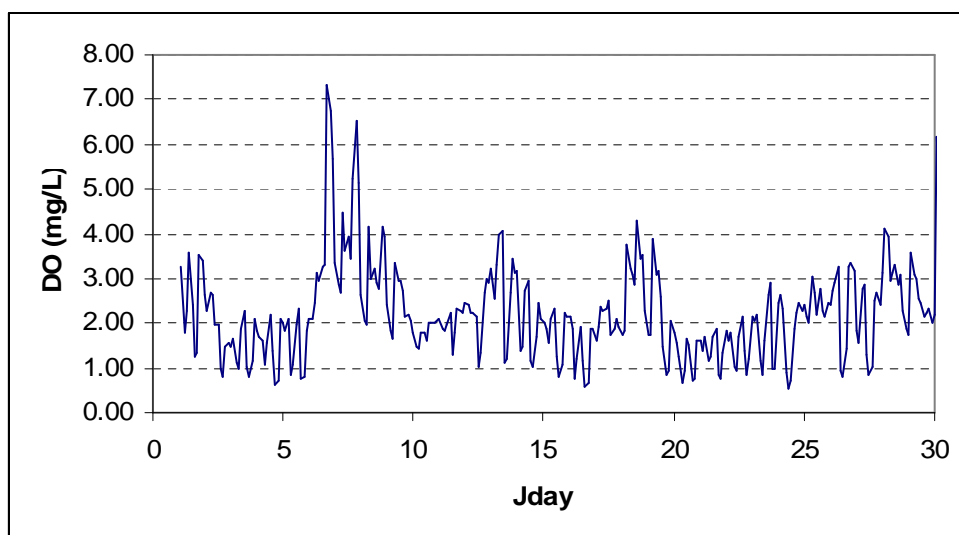


Figure 55. Modeled DO in San Elijo Lagoon

3.5.6 Santa Margarita Estuary

The Santa Margarita EFDC model was tested using tide data, weather data, and watershed WinHSPF results. The watershed inflow is shown in Figure 56. The model was run for 30 days. The modeled water surface elevation, water temperature, salinity, suspended sediment, and DO are shown in Figure 57 through Figure 60.

The modeled water surface elevation follows the tidal cycle. The modeled salinity shows strong fresh water dilution in the beginning of the simulation when watershed inflow is high. The influence of fresh water becomes weaker during the base flow period when salinity increases to near the ocean salinity level. The tidal signal of water temperature is also strong, and the modeled water temperature is more affected by the ocean. The modeled DO is lower than the saturation level due to the high ammonia input

from the watershed when the flow is high. DO increases to near the saturation level during the base flow period and is governed mainly by the ocean water DO concentration and the DO saturation level.

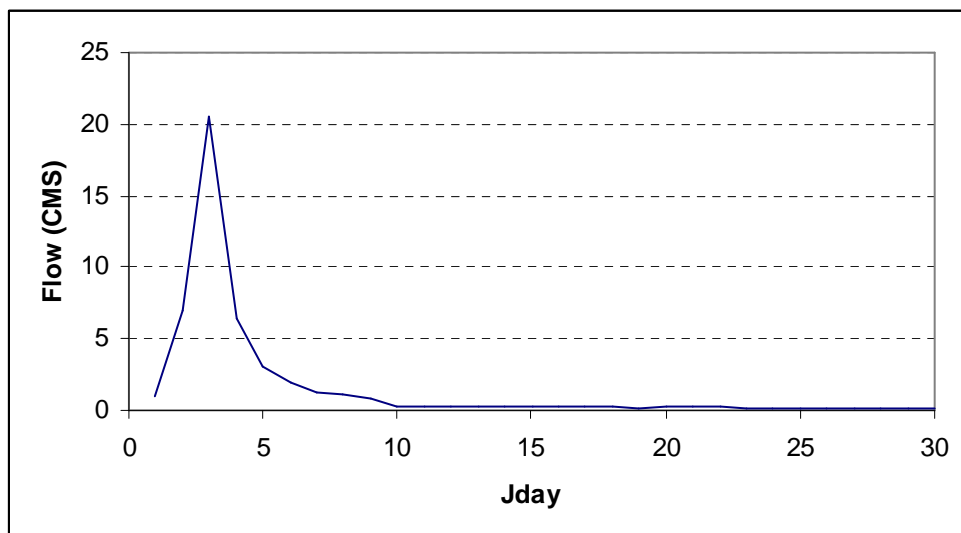


Figure 56. Watershed Inflow to Santa Margarita Estuary

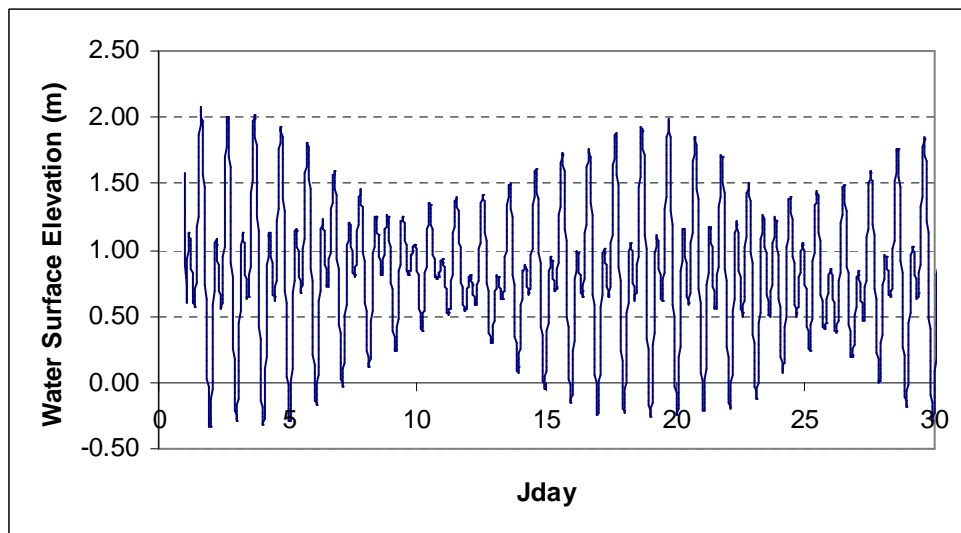


Figure 57. Modeled Water Surface Elevation in Santa Margarita Estuary

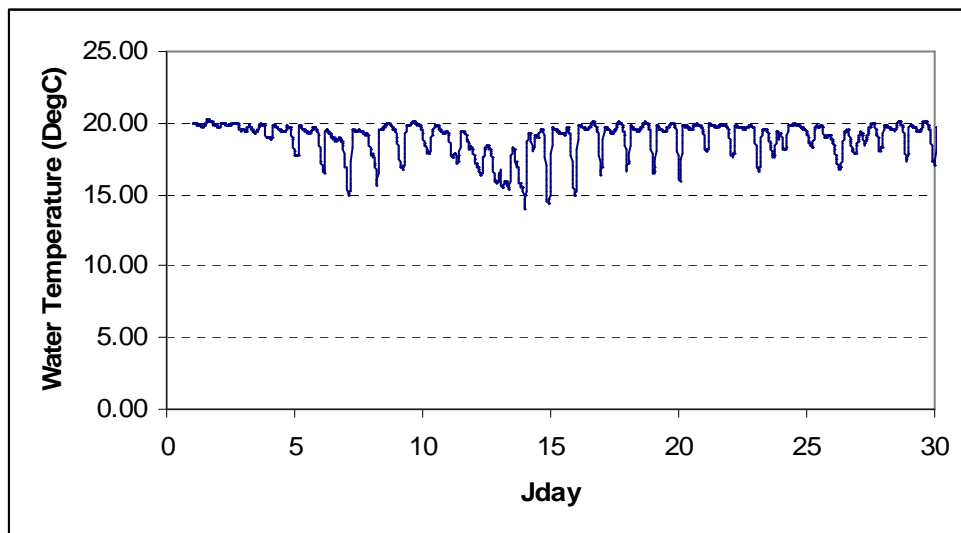


Figure 58. Modeled Water Temperature in Santa Margarita Estuary

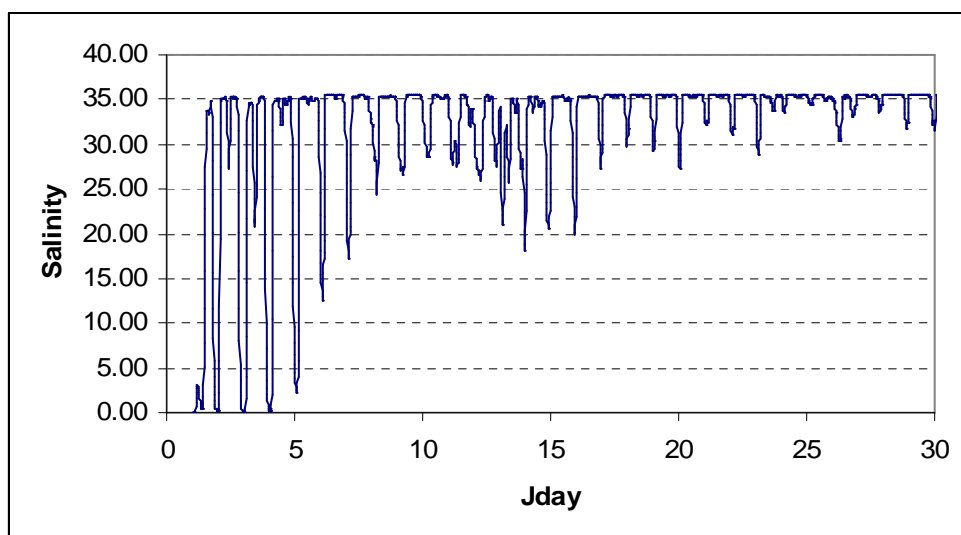


Figure 59. Modeled Salinity in Santa Margarita Estuary

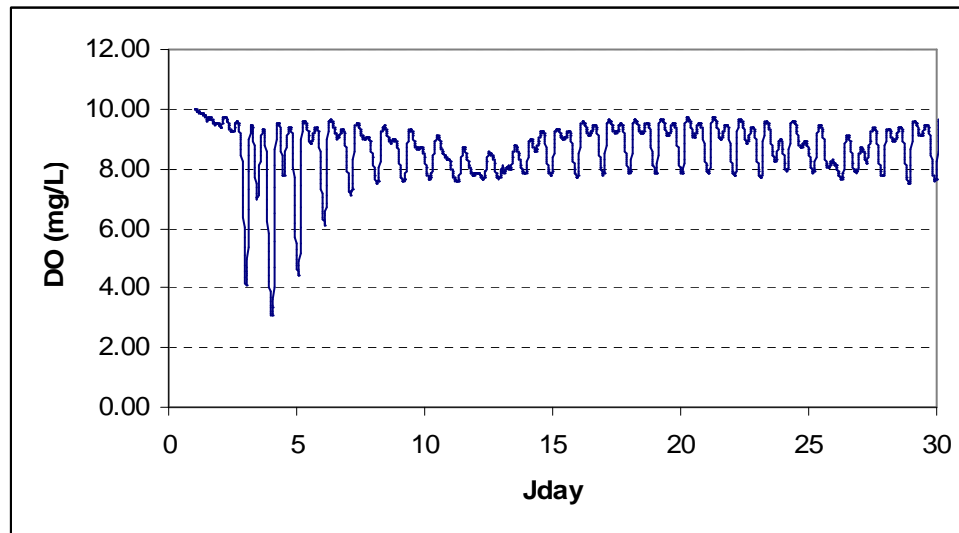


Figure 60. Modeled DO in Santa Margarita Estuary

3.6 CURRENT STATUS OF LAGOON MODELS

EFDC models have been configured for the six lagoons, and initial testing for the lagoons was conducted. The models are able to generate correct responses to the external driving forces. In general, the models can be used for the next step—calibration. However, because bathymetry data of Los Penasquitos Lagoon, San Elijo Lagoon, and Santa Margarita Estuary are not available or not sufficient for model grid development, the grids for these lagoons could require updating after the bathymetric data are collected. Additional information required to finalize the model grids is discussed below for each lagoon.

3.6.1 Agua Hedionda Lagoon

The EFDC grid will not be changed for Agua Hedionda Lagoon. However, more information is needed to finalize the model setup. The power plant withdraws a significant amount of water from the lagoon. The detailed withdrawal information such as location and rate is needed to finalize the grid.

3.6.2 Famosa Slough

Famosa Slough connects to Famosa Channel and the San Diego River through hydraulic structures including flap valves and culverts. The culvert information is available. However, the valve information is not available, and the control table cannot be established for all the hydraulic structures. When the valve information is available, it will be processed into a control table, and the model will be updated to represent the actual controlled waterbody.

3.6.3 Loma Alta Lagoon

The elevation of the sandy berm could change under the effects of tide and storm events. Because the berm elevation controls whether there is flow between the lagoon and the ocean, the elevation data should correspond to the water quality sampling period for model calibration and validation. The model will be updated when the latest elevation information is available.

3.6.4 Los Penasquitos Lagoon

Limited lagoon cross-sections are available. More bathymetry information is needed to finalize the grid of the Los Penasquitos EFDC model.

3.6.5 San Elijo Lagoon

Limited lagoon cross-sections are available. More bathymetry information is needed to finalize the grid of the San Elijo EFDC model.

3.6.6 Santa Margarita Estuary

The mouth of the Santa Margarita Estuary can change significantly. Historical pictures show that the mouth can be closed completely in certain periods. It is important to finalize the grid using the shoreline and bathymetry corresponding to the water quality sampling period.

3.7 MODEL FILES

A separate EFDC model has been created for each lagoon/estuary. The model input files are organized into folders bearing the name of the lagoon/estuary. Within each folder, standard EFDC file-naming convention is used for the input files (e.g., efdc.inp, cell.inp, etc.), so the file names are duplicated for each lagoon model.

4 Monitoring Database

Tetra Tech was tasked with building a monitoring database for the San Diego region lagoon modeling effort based on historical and recent sampling data. This section briefly describes the datasets included in the compilation to date.

To support modeling for the Bacti I and II reports, Tetra Tech compiled water quality data from Co-permittees in the subject watersheds from August 2000 through September 2004. Data was collected by 20 entities at 1,260 stations during periods ranging from May through November 2002. Additional data collected at 11 sites in the Carlsbad watershed were available for May through September in 2003 and 2004. Further data collected thus far to supplement this earlier compilation are as follows:

- In November of 2006, Nicole Rowan with CDM provided Tetra Tech with a water quality database developed by Brown & Caldwell for the Santa Margarita River. This dataset contains samples collected at 47 stations in the watershed with activity dates ranging from February 1951 to April 2002. Agency sources for this database include CAMPP, DWR, EMWD, and RCWD.
- The San Diego Water Board provided Tetra Tech with additional Santa Margarita River watershed data as well as data collected in the Los Penasquitos and Famosa Slough watersheds. The additional Santa Margarita watershed data, collected under the Surface Water Ambient Monitoring (SWAMP), was collected from January through September 2003 at five stations. Also collected under SWAMP, the Los Penasquitos watershed data was collected at five locations during March through September 2002. The Friends of Famosa collected the Famosa Slough data at six sites from January 2003 to December 2007.
- Weston Solutions developed the report for the San Diego Municipal Stormwater Copermittees' 2005-2006 Urban Runoff Monitoring in January 2007. Data were obtained from this report for the two mass loading stations (one on Santa Margarita with data available from November 2001 through February 2004 and one on Los Penasquitos with data from November 2001 through February 2005).
- MACTEC provided data collected for Loma Alta Slough, Buena Vista Lagoon, Agua Hedionda Lagoon, and San Elijo Lagoon from October through December 2007. Continuous monitoring of temperature, specific conductivity, and pH were collected. Data were also provided for Famosa Slough (19 stations) and Los Penasquitos (5 stations) covering November 2007 to February 2008. This dataset also included continuous monitoring of temperature, specific conductivity, pH, and turbidity.
- MACTEC and Weston Solutions also collected flow measurements. The data provided include 15-minute data for Carroll Canyon Creek, Carmel Creek, and Famosa Slough and daily flows measured at Loma Alta Slough, Buena Vista Lagoon, Agua Hedionda Lagoon, and San Elijo Lagoon.

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5 References

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